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Assessment of International Technologies for Superfund Applications - Technology Identification and Selection

Alliance Technologies Corp., Bedford, MA

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by

Thomas Nunno, Jennifer Hyman, Peter Spawn,
John Healy, Clay Spears, and Margaret Brown
Alliance Technologies Corporation
Bedford, MA 01730

Contract No. 68-03-3243

Project Officer

L. H. Garcia

Technical Project Monitor

E. J. Opatken
Water and Hazardous Waste Treatment Research Division
Risk Reduction Engineering Laboratory
Cincinnati, OH 45268

RISK REDUCTION ENGINEERING LABORATORY
OFFICE OF RESEARCH AND DEVELOPMENT
U.S. ENVIRONMENTAL PROTECTION AGENCY
CINCINNATI, OH 45268

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FOREWORD

Today's rapidly developing and changing technologies and industrial products and practices frequently carry with them the increased generation of materials that, if improperly dealt with, can theaten both public health and the environment. The U.S. Environmental Protection Agency is charged by Congress with protecting the Nation's land, air, and water resources. Under a mandate of national environmental laws, the Agency strives to formulate and implement actions leading to a compatible balance between human activities and the ability of natural systems to support and nurture life. These laws direct the EPA to preform research to define our environmental problems, measure the impacts, and search for solutions.

The Risk Reduction Engineering Laboratory is responsible for planning, implementing, and managing of research, development, and demonstration programs to provide an authoritative, defensible engineering basis in support of the policies, programs, and regulations of the EPA with respect to drinking water, wastewater, pesticides, toxic substances, solid and hazardous wastes, and Superfund-related activities. This publication is one of the products of that research and provides a vital communication link between the researcher and the user community.

This study was undertaken to provide a comprehensive evaluation of the many technologies that are currently under investigation or in practice by the global communities. The effort concentrated on European technologies because of their increased activity in the field of hazardous waste management.

E. Timothy Oppelt, Director
Risk Reduction Engineering Laboratory

ABSTRACT

This report summarizes the results of Phase I of a program to identify and assess international technologies that could be utilized for hazardous waste site remediation within the United States. Data was obtained through a comprehensive literature survey and through telephone contacts/interviews with agencies, industries, vendors, research groups, and others involved in the development and marketing of technologies. Emphasis was placed on technologies that have been developed and/or applied in Europe, Japan, and Canada. The factors considered in assessing the applicability of each technology were: function, operating descriptions, performance, limitations, economics, and current status. All remedial technologies identified as a result of the Phase I activities are described in this report. Recommendations are provided for further study in Phase II which will focus on the most promising international technologies.

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SECTION 1

SUMMARY AND RECOMMENDATIONS

INTRODUCTION

The purpose of this program is to identify and assess international technologies that could be utilized for hazardous waste site remediation within the United States. This report summarizes the results of PhaseI of this program, which identified international alternative technologies potentially applicable to Superfund site remediation. All remedial technologies identified as a result of the PhaseI activities are described in this report. Recommendations are also provided for further study in Phase II which will focus on the most promising international technologies.

GENERAL APPROACH

The technical approach for Phase I focused on the location, acquisition, and interpretation of existing data, studies, and related documentation for remedial technologies. Data were obtained through a comprehensive literature survey and telephone contacts/interviews with agencies, industries, vendors, research groups, and others involved in the development and marketing of technologies. Emphasis was placed on technologies that have been developed and/or applied in Europe, Japan and Canada, because of the premise that these areas have more advanced hazardous waste programs in place.

An important part of the Phase I activity was the assembly and review of information that EPA scientific personnel have obtained in their foreign travel assignments or through contact with foreign consultants or academics. A list of EPA personnel that were contacted for input to the Phase I technology identification activity is provided in Section 4, along with non-EPA contacts. A list of literature found useful to the project appears in Section 5.

SUMMARY OF RESULTS

As a result of the Phase I activities, 95 technologies have been identified that may be applicable to Superfund site remediation activity. A summary of these technologies is presented in Table 1. The technologies are grouped within the table by country and further classified in accordance with the type of technology (mobile, in situ, physical, thermal, etc.), applicability to various waste types, and status. These characteristics, in conjunction with assessments of the potential applicability of each technology, were used to develop a recommended list of candidate technologies for Phase II study. The factors considered in assessing the applicability of each technology are listed below:

- Function - purpose of the technology and its applicability.
- Description - flow schematic, discussion of theoretical operating principles and design features.
- Performance - demonstrated performance of the process for clean-up of uncontrolled hazardous waste sites.
- Limitations - physical or chemical characteristics that limit the applicability of the technology.
- Economics - the capital, operating, and maintenance costs.
- Status - current development status, availability, and research plans.

Each technology selected for Table 1 is described in a "Fact Sheet", presented in Section 3. The Fact Sheets summarize information developed during the Phase I investigation.

The preliminary screening results presented in Table 1 identify 13technologies recommended for further study under PhaseII. Technologies screened from further study include: 1) technologies that are applicable to only a small percentage of Superfund wastes; 2) technologies that are similar to conventional techniques in use in the United States; and 3) experimental technologies that are not well developed. The recommendations in Table 1 fall into three distinct categories: 1)technologies requiring no further action; 2) technologies whose status or programs should be monitored in the future; and 3) technologies for which site visits were recommended.

The screening results in PhaseI found 32 technologies for which no further action was recommended. Many of these technologies were limited to aqueous wastes representing a small portion of Superfund wastes. Other technologies were considered similar to those commonly employed or developed in the United States. Thus, technology transfer would not necessarily be beneficial in these cases.

The majority of the technologies reviewed (63 out of 95) were found to merit further review of their progress. Many of these technologies were research efforts in progress. Approximately 15 of these were NATO/CCMS (North Atlantic Treaty Organization/Committee on Challenges of a Modern Society) studies in progress. Many of these projects may become useful cleanup technologies, especially those being followed by the NATO/CCMS work.

TABLE 1. INTERNATIONAL TECHNOLOGIES FOR SUPERFUND APPLICATIONS

TECHNOLOGY	CODE	DESCRIPTION OF TREATMENT	STATUS	LOCATION	WASTE TYPE	CONTAMINANT TYPE	RECOMMENDED ACTIONS	REFERENCE
AUSTRALIA								
Ion exchange on crosslinked casein for Cr(+6) removal	A1	Selective chemical adsorption of Cr(6+) on cross-linked casein	Experimental	In process stream	Aqueous electroplating solutions and wastewater	Chromium(6+)	No further action	Technical Insights, 1986.
BELGIUM								
High-temperature slagging kiln incineration	B1	Inverted conical chamber for combustion of hard-to-incinerate hazardous wastes	Small-scale operation	Stationary	Solids and sludges	Hazardous and low-level radioactive materials	Yes; further study needed	U.S. EPA HWERL. New Frontiers, 1987.
CANADA								
Synthetic membrane retrofit with chain extractor	C1	Chain excavation and synthetic membrane placement vehicle	In patenting process	Mobile, in-situ	Soils	Various contaminants	Monitor results	NATO/CCMS- Childs, 1983.
"Kerfing" cutting for slurry floor installation	C2	The void for the slurry floor is cut with high-pressure fluid jets	Unknown	Mobile	Most types of soil	Various contaminants	Monitor results	NATO/CCMS- Childs, 1983.
Radiolytic dechlorination of polychlorinated biphenyls	C3	Dechlorination upon Exposure to high-energy radiation	Experimental	Unknown	Soils and liquids	PCBs	Monitor results	U.S. EPA HWERL. New Frontiers, 1985.
Devoe-Holbein extraction using Vitrokele compositions	C4	Synthetic molecules selectively extract metals from solution	Patented and available	Module, put in process stream	Heavy metal solutions	Heavy metals	No further action	Technical Insights, 1986.

(continued)

TABLE 1 (continued)

TECHNOLOGY	CODE	DESCRIPTION OF TREATMENT	STATUS	LOCATION	WASTE TYPE	CONTAMINANT TYPE	RECOMMENDED ACTIONS	REFERENCE
Demonstration of physical/chemical treatment of ground water at the Ville Mercier waste site	C5	Air stripping, flocculation, sand filtration and GAC treatment	Operational	Mobile	Ground water	Various organics	No further action	NATO/CCMS- Pilot Study: Demonstration, Nov. 1987. NATO/CCMS- Pilot Study: Demonstration, Mar. 1987.
PCB destruction using a diesel engine	C6	A blend of diesel fuel and PCB was test-burned in a diesel engine, effectively destroying PCBs	Experimental	Unknown	Liquids	PCBs	No further action	OECD- Lindsey, 28-30 April 1982.
Downflow stationary fixed-film reactors	C7	An anaerobic reactor with stationary films in vertical channels	Commercially available	Stationary	Unknown	Anaerobically-biodegradable contaminants	Follow-up recommended	Technical Insights, 1986.
DENMARK								
Aerobic degradation of contaminated soil at Skrydstrup, Denmark	D1	Biological composting: layering with activated sludge and recirculating the leachate	Field testing	Mobile	Soil	Chlorinated organics, acids, paints and paint sludges	Monitor results	NATO/CCMS- Pilot Study: Demonstration, Nov. 1987. NATO/CCMS- Pilot Study: Demonstration, Mar. 1987.

(continued)

TABLE 1 (continued)

TECHNOLOGY	CODE	DESCRIPTION OF TREATMENT	STATUS	LOCATION	WASTE TYPE	CONTAMINANT TYPE	RECOMMENDED ACTIONS	REFERENCE
Anaerobic degradation of contaminated soil at Skrydstrup, Denmark	D2	Biological composting: layering with sludge from anaerobic digesters, leachate recirculation, impermeable membrane cover	Field testing	Mobile	Soil	Chlorinated organics, acids, paints and paint sludges	Monitor results	NATO/CCMS- Pilot Study: Demonstration, Nov. 1987. NATO/CCMS- Pilot Study: Demonstration, Mar. 1987.
Aerobic degradation in the unsaturated zone with co-metabolism by oxidation of methane and/or propane gas	D3	Adapted bacteria and injection of a gas/air mixture to promote biodegradation	Lab and field studies	In-situ	Lower soil layers	Chlorinated solvents	Monitor results	Christiansen, 1987.
Anaerobic biodegradation in the contaminated zone by addition of sodium acetate	D4	Methanogene bacteria and sodium acetate to promote reductive dechlorination	Field studies	In-situ	Deep soil layers	Chlorinated solvents	Monitor results	Christiansen, 1987.
FEDERAL REPUBLIC OF GERMANY								
Ground water treatment by aeration and nutrient addition	G1	Biological: aeration, nutrient addition, and re-injection	Unknown	In-situ	Ground water	Hydrocarbons and other organics	Update status	NATO/CCMS- Childs, 1983.
Encapsulation/Stabilization techniques using thermoplasts and resins	G2	Thermoplasts and resins to stabilize, HDPE membranes to encapsulate	Various stages of development	In-situ	Soils	Various contaminants	Update status	TNO- Assink, van Den Brink, 1986.
Low-alkaline, waterglass grouting- Dynagrout	G3	Low-alkaline silicate gel with a high SiO /Na O ratio	Successfully demonstrated	In-situ	Soils	Various contaminants	Update status	Brown, 1987. TNO- Assink, van Den Brink, 1986.

(continued)

TABLE 1 (continued)

TECHNOLOGY	CODE	DESCRIPTION OF TREATMENT	STATUS	LOCATION	WASTE TYPE	CONTAMINANT TYPE	RECOMMENDED ACTIONS	REFERENCE
Mechanical separation of contaminated, dredged materials	G4	A hydrocyclone and an elutriator separate contaminated fines from coarse material	Pilot plant	Mobile	Sludge	Heavy metals	Update status	Bruce, 1986.
Continuous High-Pressure (CHP) filter press	G5	Solid/liquid separation of sludge-like suspensions	Full scale	Mobile	Sludges and slurries	Various contaminants	Monitor progress	Bruce, 1986.
In-situ aerobic biodegradation of aromatic hydrocarbons	G6	Biodegradation using nitrate and nutrient-enriched injection water	Developmental	In-situ	Ground water	Benzene and other aromatic hydrocarbons	Further study useful	U.S. EPA HWERL. New Frontiers, 1987.
Solidification/stabilization of acid resin in soils by the addition of lime	G7	Lime stabilizes acid resin by polymerization of the tar constituents	Unknown	In-situ	Soils and sludges	Acid resins	No further action	Wiedemann, Umweltbundesamt, 1982.
Engineered salt cavern ultimate disposal	G8	Construction of a salt mine for permanent haz. waste disposal	One facility operating	Stationary	Solids and sludges	Some waste restrictions	Check status	Schneider, 1988. Stone, 1984. Texator, 1988. U.S. EPA HWERL. New Frontiers, 1987.
Salt mine disposal and storage-Herfa-Neurode facility	G9	Disposal and storage of hazardous wastes	One facility operating	Stationary	Solids and sludges	Some waste restrictions	Update status	Gulevich, 1984. Proctor, 1982.

(continued)

TABLE 1 (continued)

TECHNOLOGY	CODE	DESCRIPTION OF TREATMENT	STATUS	LOCATION	WASTE TYPE	CONTAMINANT TYPE	RECOMMENDED ACTIONS	REFERENCE
In-situ oxidation of arsenic in ground water using potassium permanganate ($KMnO_4$)	G10	Oxidation of As(+3) to As(+5) and precipitation of As-Fe-Mn compounds	Developmental	In-situ	Ground water or sludges	Arsenic compounds	Check status	Matthess, 1981. Matthess et al., 1983. NATO/CCMS- Smith, Feb. 20, 1984.
In-situ anaerobic biodegradation of hydrocarbons in the subsurface	G11	Biodegradation of HCs to water and CO with nitrate addition	Experimental	In-situ	Ground water	Hydrocarbons	Further study useful	Baitermann, 1983.
Mobile rotary kiln treatment of contaminated soil at Unna-Boenen	G12	Directly and indirectly heated rotary kiln	Expected to be operational (1987)	Mobile	Soils	Aromatics, tars and acid resins	Monitor results	NATO/CCMS Pilot Study: Demonstration, Mar. 1987.
Soil cleaning by extraction at the Pintsch site	G13	Multi-phase extractor and wastewater treatment	Operational	Mobile	Soils	Organic contaminants	Yes; further study needed	NATO/CCMS Pilot Study: Demonstration, Mar. 1987.
Ground water treatment at the Pintsch site	G14	Oil/water separator, flotation, air stripping tower, and filters	Operational	Mobile	Ground water	Hydrocarbons, phenols, and oils	Yes; further study needed	Brown, 1987. NATO/CCMS Pilot Study: Demonstration, Mar. 1987.
Remediation of diesel fuel contamination using ozone	G15	Oxidation of organics and enhanced biodegradation by ozone treatment	Operational	Mobile	Ground water	Diesel fuel and organics	Monitor results	Nagel, 1982.

(continued)

TABLE 1 (continued)

TECHNOLOGY	CODE	DESCRIPTION OF TREATMENT	STATUS	LOCATION	WASTE TYPE	CONTAMINANT TYPE	RECOMMENDED ACTIONS	REFERENCE
Klockner high-pressure water jet soil washing system	G16	High-pressure water jets force off toxins adsorbed to soil particles	Patented, pilot scale	Mobile	Soils	Various contaminants	Monitor results	Brown, 1987. NATO/CCMS Pilot Study: Demonstration, Mar. 1987.
The LECO System, using DCR, for solidifying special wastes and stabilizing contaminated soils	G17	CaO and hydrophobic agents stabilize and disperse oils	Operational	In-situ or on-site	Slurry ponds and soils	Mineral oils	Further study useful	Klockner, 1987. Steiff, Undated. Wiedemann, Umweltbundesamt, 1982.
Biological remediation of soil and water using the IAT-Biosystem	G18	Aerobic biodegradation using specialized substrates, bacteria, enzymes and nutrients	Operational	In-situ	Primarily soils	Mineral oil and hydrocarbons	Yes; further study needed	Brown, 1987.
Lab cultivation of specific micro-organisms for the decontamination of abandoned sites	G19	Cultivation in lab of micro-flora taken from sites for future use	Experimental	In-situ	Soils	Biodegradable or leachable contaminants	Monitor results	Brown, 1987.
Shell BIOREG Process for onsite cleanup of contaminated soil	G20	Bacteria developed for new and used oils; substrate, milled pine bark	Operational	In-situ	Soils	Hydrocarbons and similar pollutants	Further study useful	Brown, 1987.
EFEU flush gas distillation of contaminated earth	G21	Distillation in a rotary kiln	Patented, experimental	Unknown	Soils	Distillable contaminants (i.e. some hydrocarbons)	Yes; further study needed	Brown, 1987.

(continued)

TABLE 1 (continued)

TECHNOLOGY	CODE	DESCRIPTION OF TREATMENT	STATUS	LOCATION	WASTE TYPE	CONTAMINANT TYPE	RECOMMENDED ACTIONS	REFERENCE
Onsite soil cleaning using the "Oil CREP System"	G22	Oil washed from soil forming a separable emulsion, H2O recyclable	Operational	Mobile	Soils	Oils with heavy metals	Yes; further study needed	Brown, 1987.
Thermal cleaning of soils contaminated primarily with organics	G23	Rotary kiln to oxidize high boiling point and hard-to-burn substances	Bench-scale	Mobile	Soils	Coal, tar, oils, mercury, cyanide and heavy metals	Further study useful	Brown, 1987.
Chlorinated hydrocarbon remediation by high-pressure suction	G24	Suction of volatile contaminants from unsaturated soils	Pilot-scale	In-situ (mobile)	Soils	Highly volatile hydrocarbons	Yes; further study needed	Brown, 1987.
Use of specially-adapted microorganisms to clean contaminated soil	G25	Four different methods of introducing the bacteria to the site are studied	Operational	In-situ	Soils	Heating and diesel oil, gasoline, kerosene, phenols and formaldehyde	Update status	Brown, 1987.
Root zone bed treatment of organics	G26	Biological activity of the root zone of reed beds is used for treatment	Experimental in the field	Offsite	Ground water, leachate	Organics	Update status	Shimell, 1987.
FINLAND								
Ekokem commercial TSDF- Finland	FD1	Incineration and physical-chemical treatment plants	Operational	Stationary	Wastewater, sludges, and possibly solids	Various contaminants	No further action	Chem. Eng. Abstr., 1987.
FRANCE								
Rhone-Poulenc/Vicarb process for Valorization of Chlorinated Residues (VCR)	F1	Pyrolytic process with a burner and very short retention times necessary	Several units now in operation	Stationary	Solids, liquids, gases	Chlorinated organics (including PCBs)	Update status	Vicarb, 1986.

(continued)

TABLE 1 (continued)

TECHNOLOGY	CODE	DESCRIPTION OF TREATMENT	STATUS	LOCATION	WASTE TYPE	CONTAMINANT TYPE	RECOMMENDED ACTIONS	REFERENCE
Petrifix stabilization process at the Gerland dump site	F2	Chemical neutralization and stabilization (specific chemicals not mentioned in literature)	Operation completed in 1983	Mobile	Solids & sludges	Acid tars/ oil refinery wastes	Update status	NATO/CCMS Pilot Study: Demonstration, Mar. 1987.
The Neostar process: High-temperature/high-pressure steam cracking of PCBs	F3	Destroys PCBs without producing furans or dioxin	Pilot plant	Stationary, potentially mobile	Liquids	PCBs	Monitor progress	Kazmierczak, 1987.
Cationic metals recovery from effluent waste streams	F4	Electrochemical displacement of metals by iron in a vibrating reaction vessel	Unknown	Stationary	Metals in solutions	Valuable or toxic metals	No further action	Chem. Eng. Abstr., 1987.
Actimag magnetic separation	F5	Magnets agitate a bed of iron for substitution with metals from solution	Pilot plant	Stationary	Metals in solution	Valuable or toxic metals	No further action	Engineer, 1987.
Organic carbon conversion in a High Compacting Multiphasic Reactor (HCMR)	F6	A large-particle spouted bed for aerobic biological treatment	Experimental	Stationary or mobile	Multiphase wastes	Organics and hydrocarbons	No further action	Elmaleh, 1987.
An active denitrification medium to promote anaerobic biodegradation	F7	Denitrifying bacteria, organic carbon and calcium nitrate as active support	Bench-scale and patented	Stationary	Unknown	Anaerobically-biodegradable contaminants	No further action	Technical Insights, 1986.

(continued)

TABLE 1 (continued)

TECHNOLOGY	CODE	DESCRIPTION OF TREATMENT	STATUS	LOCATION	WASTE TYPE	CONTAMINANT TYPE	RECOMMENDED ACTIONS	REFFRENCE
HUNGARY								
Catalytic hydrodehalogenation	H1	A supported palladium catalyst replaces Cl atoms with H atoms	Experimental lab stage and patented	Stationary	Liquids	Chlorinated compounds	No further action	Mathe, 1987.
Waste elimination by application of the plasma technique	H2	Plasma decomposition of vaporized wastes	Full-scale unit	Stationary	Liquids	Most wastes including metals and halogenated hydrocarbons	Monitor program	Krajcsovics, 1987.
INDIA								
DDT Degradation by bacteria from activated sludge	I1	Aerobic biodegradation by isolated microorganisms	Experimental	Potentially mobile	Soils	DDT	No further action	Sharma, 1987.
Microbial detoxification of cyanide from wastewater	I2	Aerobic biodegradation by specific microbial sludge	Experimental	Unknown	Wastewater	Cyanide	No further action	U.S. EPA HWERL. New Frontiers, 1985.
JAPAN								
Degradation of PCBs by microorganisms	J1	Biodegradation by the bacterium Alkaligenes	Experimental	Not yet determined	Soil	PCBs	Update status	Yagi, Undated.
Fujibeton encapsulation process	J2	Encapsulation using a cross-linked silicate material	Commercially available	Mobile	Still bottoms, semisolids, and sludge	Chlorinated organics and electroplating wastes	Update status	Technical Insights, 1986.

(continued)

TABLE 1 (continued)

TECHNOLOGY	CODE	DESCRIPTION OF TREATMENT	STATUS	LOCATION	WASTE TYPE	CONTAMINANT TYPE	RECOMMENDED ACTIONS	REFERENCE
Electrolytic decomposition of iron-cyanide complexes	J3	Practical electrolytic decomposition	Patented	Stationary	Aqueous solutions	Ferrocyanide and ferricyanide complexes	No further action	Technical Insights, 1986.
Biological treatment of phosphorous compounds	J4	Accumulation of phosphorous compounds by specific microorganisms	Patented	Mobile	Aqueous solutions	Organic and inorganic phosphorous compounds	No further action	Technical Insights, 1986.
HWT chemical fixation technology	J5	Chemical fixation and detoxification in the building of a macromolecular framework using inorganic polymers	Demonstration	Mobile	Soils	Inorganic and organic wastes	Update status	International Waste Technologies Undated. McCoy, 1987.
Removal of arsenic by precipitation and sedimentation	J6	Precipitation by addition of H_2SO_4, NaOCl, and $FeCl_3$	Operational	Stationary	Wastewater and steam from a geothermal power generating plant	Arsenic	No further action	U.S. EPA HWERL. New Frontiers, 1985.
Removal of arsenic and gallium by precipitation	J7	Co-precipitation by addition of $Fe(OH)_3$, $FeCl_3$, and NH_4OH	Operational	Stationary	Wastewater from semiconductor processing	Arsenic and gallium	No further action	U.S. EPA HWERL. New Frontiers, 1985.
Removal of arsenic from low pH wastewaters	J8	Addition of dialkyl thiocarbamate as a chelating agent	Patented and available	Stationary	Wastewater from cadmium refining	Arsenic	No further action	U.S. EPA HWERL. New Frontiers, 1985.
Removal of low concentrations of arsenic using a chelating resin	J9	Addition of a Amberlite IRA 743, a chelating resin	Patented and available	Stationary	Wastewater or Ground water	Arsenic	No further action	U.S. EPA HWERL. New Frontiers, 1985.

(continued)

TABLE 1 (continued)

TECHNOLOGY	CODE	DESCRIPTION OF TREATMENT	STATUS	LOCATION	WASTE TYPE	CONTAMINANT TYPE	RECOMMENDED ACTIONS	REFERENCE
Treatment of arsenic-containing wastewaters with titanium compounds	J10	Selective precipitation by addition of titanium	Process available	Stationary	Wastewater or ground water	Arsenic	No further action	U.S. EPA HWERL. New Frontiers, 1985.
Adsorption of arsenic by red mud	J11	Red mud shaken with wastewater adsorbs arsenic	Experimental	Stationary	Wastewater	Arsenic	No further action	U.S. EPA HWERL. New Frontiers, 1985.
Plunging water jet system using inclined short nozzles for aerobic treatment of wastewater	J12	Aeration for biological treatment and removal of dissolved organic matter	Experimental	Unknown	Wastewater	Organics	No further action	Ohkawa, 1986.
Mercury roasting of contaminated soils	J13	Mercury is volatilized from soils and recovered	Full-scale unit	Stationary	Soils	Mercury	Update status	Ikeguchi, 1987.
THE NETHERLANDS								
Extraction techniques for treatment of soil in the Netherlands (Overview)	N1	Physical/chemical	Five full-scale units in operation	Varies	Soils	Various contaminants	Monitor results	NATO/CCMS Pilot Study: Demonstration, Mar. 1987.
BSN soil extraction plant	N2	Extraction by high pressure washing, separation and dewatering	Full-scale unit	Mobile	Soils	Various contaminants	Check status	TNO: Assink, van Den Brink, 1986.
Heijmans soil extraction plant	N3	Extraction by scrubbing, precipitation, separation and dewatering	Full-scale unit	Mobile	Soils	Cyanides, heavy metals, and hydrocarbons	Yes; further study needed	TNO: Assink, van Den Brink, 1986.

(continued)

TABLE 1 (continued)

TECHNOLOGY	CODE	DESCRIPTION OF TREATMENT	STATUS	LOCATION	WASTE TYPE	CONTAMINANT TYPE	RECOMMENDED ACTIONS	REFERENCE
HWZ Bodemsanering mobile soil extraction plant	N4	Scrubbing, washing with NaOH, dewatering and separation	Full-scale unit	Mobile	Soils	Mineral oils, aromatics, PNAs, metals, cyanides, some chlorinated hydrocarbons	Yes; further study needed	TNO- Assink, van Den Brink, 1986.
Ecotechniek soil washing process	N5	Sand slurry is heated with steam, oil is skimmed sand dewatered	Full-scale unit	Unknown	Sand	Oils	Check progress	TNO- Assink, van Den Brink, 1986.
Thermal treatment of soil in the Netherlands (Overview)	N6	Thermal- generally rotary kiln or fluidized bed	Five full-scale units in operation	Stationary	Soils	Petroleum compounds, PCAs, cyanides and BTEX	Monitor results	NATO/CCMS Pilot Study: Demonstration, Mar. 1987.
The ATM Rotary Kiln for Soils	N7	Direct heating dual rotary kilns and incinerator (afterburner)	Full-scale unit	Stationary	Soils	Petroleum compounds, PCAs, cyanides and BTEX	Check status	TNO- Assink, van Den Brink, 1986.
Boskalis-Esdex Fluidized Bed Furnace for soils	N8	Fluidized bed furnace with oil injection	Pilot-scale plant	Stationary	Soils	Petroleum compounds, PCAs, cyanides and BTEX	Monitor program	TNO- Assink, van Den Brink, 1986.
Ecotechniek Rotary Kiln Tubular Furnace for soils	N9	Direct and indirectly heated rotary kiln with afterburner	Full-scale unit	Stationary	Soils	Petroleum compounds, PCAs, cyanides and BTEX	Check status	TNO- Assink, van Den Brink, 1986.
NBM indirectly-heated tube furnace for soils	N10	Air-tight rotary kiln, indirectly-heated, with inert gas flow	Full-scale unit	Stationary	Soils	Petroleum compounds, PCAs, cyanides and BTEX	Check status	NBM Brochure, 1986. TNO- Assink, van Den Brink, 1986.

(continued)

TABLE 1 (continued)

TECHNOLOGY	CODE	DESCRIPTION OF TREATMENT	STATUS	LOCATION	WASTE TYPE	CONTAMINANT TYPE	RECOMMENDED ACTIONS	REFERENCE
Landfarming efforts in the Netherlands	N11	Biological	Demonstration stage	In-situ	Soils	Gas oil, fuel oil, cutting oil, PCAs	Monitor results	NATO/CCMS Pilot Study: Demonstration, Mar. 1987.
In-situ biorestoration of soil contaminated with gasoline	N12	Biological	Demonstration stage	In-situ	Soils	Gasoline	Yes; further study needed	NATO/CCMS Pilot Study: Demonstration, Mar. 1987.
Bioreactor research	N13	Special micro-organisms and process control	Experimental	In-situ and mobile	Soils, clay	Contaminants of low biodegradability	Monitor results	NATO/CCMS Pilot Study: Demonstration, Mar. 1987.
Reclamation of contaminated soil with a bioreactor	N14	A three-phase slurry aerated and suspended by air injected from below	Lab scale	Mobile	Soils	Various hydrocarbons	Update status	Kleijntjens, 1987. TNO Assink, van Den Brink, 1986.
Electrochemical treatment of organohalogens	N15	Electrochemical removal of chlorine atoms from organic molecules	Experimental	Unknown	Wastewater and rinsewater	Polar or ionic organochlorine compounds	Yes; further study needed	Schmal, et al., 1987. Technical Insights, 1986.
Extraction of organic bromine compounds from soils using NaOH	N16	Intimate mixing with NaOH extracts bromine	Pilot plant	Onsite	Soils	Bromine compounds	Yes; further study needed	Rulkens, et al, Undated.
The Panel wall as a barrier	N17	Barrier of alternating steel reinforcing tubes and panels formed in-situ	Unknown	In-situ	Soils	Various contaminants	Monitor progress	NATO/CCMS: Childs, 1985.
Boundary Film Evaporators with carbon	N18	Volatile compound put into air phase, removed by activated carbon filter	Unknown	Mobile	Ground water	Volatile organics	Yes; further study needed	TNO Assink, van Den Brink, 1986.

(continued)

TABLE 1 (continued)

TECHNOLOGY	CODE	DESCRIPTION OF TREATMENT	STATUS	LOCATION	WASTE TYPE	CONTAMINANT TYPE	RECOMMENDED ACTIONS	REFERENCE
Air stripping of volatiles in ground water	N19	Aeration towers or plate aerators	Unknown	Mobile or stationary	Ground water	Volatile organics	No further action	TNO- Assink, van Den Brink, 1986.
Microfiltration of zinc-contaminated ground water	N20	Zinc separated as zinc hydroxide flocs, removed by membrane filtration	Unknown	Mobile or stationary	Ground water	Zinc	No further action	TNO- Assink, van Den Brink, 1986.
Decontamination of excavated soil by composting	N21	Soil is aerated and composted, exhaust air passed through a compost filter	Pilot-scale	Off-site	Soils	Gasoline	Update status	TNO- Assink, van Den Brink, 1986.
Specialized microbial degradation of excavated soil	N22	Specialized micro-organisms for high-rate biotreaters	Experimental	Off-site	Soils	Halogenated hydrocarbons	Update status	TNO- Assink, van Den Brink, 1986.
In-situ steam stripping of soils	N23	Steam volatilizes contaminants and is medium of transport	Pilot plant	In-situ	Soils	Various hydrocarbons	No further action	TNO- Assink, van Den Brink, 1986.
Steam Stripping of excavated soil	N24	Steam volatilizes contaminants and is medium of transport	Bench-scale	Mobile	Soils	Volatile contaminants	No further action	Assink, 1987. Jonker, 1988.
DHV pelletizing process for metal-plating sludge	N25	Pure granular metal-carbonate crystals are produced in a reactor; pellets are reusable	Unknown	Stationary	Metal-plating and pickling baths	Metals	No further action	Chem. Eng. Abstr. 1987.
Washing of cadmium-polluted soils	N26	Soil washing then water treatment by sorption with resin GI-73	Pilot-scale	In-situ	Soils and ground water	Cadmuim	Yes, further study needed	Urlings, 1987.

(continued)

TABLE 1 (continued)

TECHNOLOGY	CODE	DESCRIPTION OF TREATMENT	STATUS	LOCATION	WASTE TYPE	CONTAMINANT TYPE	RECOMMENDED ACTIONS	REFERENCE
SWEDEN								
Anodic oxidation of cyanide	S1	Agitation-enhanced electrolytic oxidation	Patented, experimental	Unknown	Cyanide solutions (electroplating baths)	Cyanide	No further action	Technical Insights, 1986.
Heavy metal removal via sulfate-reducing bacteria	S2	Bacteria reduce sulfate to sulfides; heavy metals precipitate out as sulfides	Patented, mostly experimental	Unknown	Heavy metal aqueous solutions	Sulfate, copper, zinc and iron	No further action	Technical Insights, 1986.
SAKAB Norrtorp rotary kiln incinerator	S3	Rotary kiln, 12 meters long	Operational since 1983	Stationary	Liquids, sludges and solids	Various comtaminants	No further action	Dial, 14-27 April 1985.
UNITED KINGDOM								
The electro-reclamation of chlorine and sodium from soils	U1	Migration of ions in soil to an electrode to facilitate extraction	Experimental	In-situ	Soils	Metals or other ions	No further action	Hamnett, 1980.
The Macguire VO2 aeration system for biological enhancement	U2	Aeration to enhance aerobic biodegradation	Available	Stationary	Sludge	Biodegradable contaminants	No further action	Processing, 1986.

The last category includes a list of 14 technologies selected for site visits. Among the selected technologies, two thermal technologies, two biological remedial technologies, and 10 physical/chemical techniques are found. A listing of the technologies selected for further research and their associated contacts are given in Table 2.

The reasons for selecting these technologies varied significantly as shown in Table 2. Although thermal treatment technologies abound elsewhere as they do in the United States, they have been covered by the NATO/CCMS work and frequently employ the same principles of operation as in the United States. Thus, this project did not select many thermal technologies. Several soil washing technologies were selected due to their extensive use in Europe and high throughputs compared to the United States' washers. Other technologies were selected for their unique applications or operational principles. Finally, a few technologies will be reviewed to understand why they failed, so that United States' researchers can benefit from this knowledge.

TABLE 2. TECHNOLOGIES SELECTION FOR FURTHER STUDY UNDER PHASE II

Technology	Code	Contact(s), Company, Tel. No.	Reason for selection
Belgium			
High-temperature slagging kiln incineration (HTSI).	B1	Rik Vanbrabant, Project Leader Belgian Nuclear Research Center (SCK/CEN) Waste Treatment Dept. Boeretang 200 B-2400 Mol, Belgium 011-32 14 31 68 71	Unique process.
Federal Republic of Germany			
Soil cleanup using low frequency vibration-Pintsch site.	G13	Herr Werner/Mr. Groschel Harbauer GmbH & Co. KG Ingenieurburo fur Umwelttechnik Bismarckstrasse 10-12 1000 Berlin 12, FRG 011-49 30 341-19-12	Unique approach.
Ground water treatment at the Pintsch site.	G14	Dr. Sonnen Harbauer GmbH & Co. KG Bismarckstrasse 10-12 D-1000 Berlin 12, FRG 030-341-1912	Integral to soil clean-up at Pintsch site (see G13)
Biological remediation of soil and water using the IAT-Biosystem.	G18	Mr. Lissner/Mr. Henke Umweltschutz Nord GmbH Bergedorfer Strasse 49 2875 Ganderkesee 1, FRG 011-49-4222 1023	Unique approach to biorestoration.
EFEU flush gas distillation of contaminated soil.	G21	H. Michel Kim - EFEU GmbH Ackerstrasse 71-76 1000 Berlin, FRG 011-49-30-4894-672,673	Unique process.

(continued)

TABLE 2 (Continued)

Technology	Code	Contact(s), Company, Tel. No.	Reason for selection
Federal Republic of Germany (cont.)			
Onsite soil cleaning using the TBSG Oil CREP System.	G22	Dr. Peterson/Herr Gunchera TBSG Industrievertratungen GmbH Langerstrasse 52-54 2800 Bremen 1, FRG	Unique process, high throughput.
Chlorinated hydrocarbon remediation by high-pressure suction.	G24	Dr. Stein/Dr. Wolff Hanover Umwelttechnik GmbH Impexstrasse 5 6909 Waldorf, FRG 49-622 79 051	Similar process to U.S. technology. Need information on application and performance.
The Netherlands			
Metals extraction by soil washing.	N3	Mr. C. Jonker Mr. Martine Heijmans Heijmans Milieutechniek BV P.O. Box 2 5240 BB Rosmalen, the Netherlands 011-31-4192-89111	Effective soil washer.
Mobile soil washer for removing cyanide from contaminated soil.	N4	H.C.M. Breek HWZ Bodemsanering Vanadiumweg 5 3812 PX Amersfoort, the Netherlands 011-31-33-1 38 44	High throughput soil washer.

(continued)

TABLE 2 (Continued)

Technology	Code	Contact(s), Company, Tel. No.	Reason for selection
The Netherlands (cont.)			
In situ biorestoration research.	N12	Dr. Reinier van den, Berg Ms. Esther R. Soczo RIVM Antonie van Leeuwenhoeklaan 9 Postbus 1 3270 BA Bilthoven, The Netherlands 011-31-30-743338	Extensive biorestoration research program with long history.
Electrochemical treatment of organohalogens in process waste waters.	N15	Dr.-Ir D. Schmal TNO/Dept. of Environ. Technology P.O. Box 217 2600 AE Delft Schoemakerstraat 97 2628 VK Delft, The Netherlands 011-31 15 69 6087	Unique process. May have future application.
Extraction of organic bromine compounds from soils.	N16	Dr. W.H. Rulkens, and Jan W. Assink - TNO Div. of Technology for Society	Unique application of soil washing.
Boundary film evaporators with carbon.	N18	A.B. van Luin Ground Water Institute P.O. Box 17 8200 AA Lelystad, the Netherlands 011-31-3200-70411	Unique process with some problems.
In situ washing of cadmium-polluted soils (site in Utrecht)	N26	Mr. L.G.C.M. Urlings Head, Research & Development TAUW Infra Consult BV P.O. Box 479 7400 AL Deventer, The Netherlands 011-31-5700-999-11	Also, high throughput soil washing application.

SECTION 2

OVERVIEW OF HAZARDOUS WASTE MANAGEMENT PROGRAMS IN FOREIGN COUNTRIES

INTRODUCTION

Hazardous waste management in countries throughout the world is an evolving practice, one which involves continually developing policies and regulatory approaches to the problems posed by hazardous waste production and disposal. Most technologically-advanced countries have developed a wide variety of technologies for dealing with hazardous waste problems, in addition to sponsoring significant research and development efforts in the field.

The European approach to hazardous waste management is notable because of its relative success. The Europeans practice decentralization, whereby individual counties or provinces most often assume the responsibility for the collection and disposal of hazardous wastes produced in their locality. Still, while implementation of hazardous waste management systems is often a local responsibility, most countries do have a National Environmental Protection Agency which creates the environmental policy for the country, develops the regulatory framework for meeting the goals of that policy, and serves to disseminate information on hazardous waste treatment and disposal.

Along with decentralization has arisen the development of organized collection and transport systems designed to meet the unique needs of each locality. Problems do arise, however, out of the lack of uniformity of environmental regulation and policy enforcement throughout the country, in addition to the lack of local facilities available for proper waste disposal. Some European countries including the Netherlands, Sweden and Denmark have constructed centralized incineration facilities and landfills which accept wastes from all over the country, in response to the shortage of local facilities.

The exporting of hazardous wastes to neighboring countries, practiced in the Federal Republic of Germany for example, is also a common practice of countries lacking proper disposal facilities of their own. Examples of other less conventional waste disposal practices are co-disposal of hazardous wastes with municipal wastes seen in the United Kingdom, and disposal at sea, practiced in the FRG, Japan and Australia.

Throughout the world, the high costs of disposal often incurred upon local municipalities and entrepreneurs, along with the lack of proper disposal facilities, tends to result in numerous incidences of illegal dumping. This is especially true in the more populated and politically-reactive developing countries where enforcement poses unique difficulties. This, along with the fact that environmental regulations are only a recent phenomenon, give rise to the contemporary issue of what to do with old, abandoned, contaminated waste sites, known or suspected to exist in large quantities throughout these countries.

Most foreign countries are only beginning to catalogue their abandoned sites with no country surveyed yet having a regulatory mechanism for the remediation of such sites as sophisticated as the United States' Comprehensive Environmental Response Compensation and Liabilities Act (CERCLA). The Canadian Council of Resource and Environmental Ministers (CCREM), however, is currently working on establishing a "national contingency fund" to respond to the problem of abandoned sites in Canada. Most central governments are responding to the problem of abandoned hazardous waste sites by directing nationwide studies and providing subsidies to local communities for remediation efforts. However, it is likely in the near future that in most European communities, the restoration of abandoned hazardous waste sites will continue to be a local affair.

The following sections provide an overview of the current state of hazardous waste management practices for each of the individual countries addressed in this report. Hazardous waste management in Hungary and Finland has not been covered due to a lack of available information from these countries.

The most thorough and current information on hazardous waste management in Denmark, France, Japan and The Netherlands was found primarily in "International Perspectives on Hazardous Waste Management", published this year by the Academic Press and edited by William Forester and John Skinner. The other major sources for the information found in this section are:

- Arnott, Robert A. Non-Regulatory Aspects of European Waste Management, 1984.
- Biles, Stan. A Review of Municipal and Hazardous Waste Management Practices and Facilities in Seven European Countries, 1987.
- Williams, Alan C. A Study of Hazardous Waste Minimization in Europe: Public and Private Strategies to Reduce Production of Hazardous Waste, 1986.

AUSTRALIA OVERVIEW

In 1982, the management of hazardous wastes in Australia was the subject of a broad ranging study undertaken by the Australian Environment Council (AEC) and the Confederation of Australian Industry. The goal of this study was to commence the management of hazardous wastes and to achieve a marked improvement in environmental standards and safeguards, without massive investment or conflict between government and industry and, therefore, without jeopardizing the economic viability of those industries.

Harzardous wastes arising from industrial operations were not specifically cared for by dedicated systems for their management. The main concern was to keep these wastes out of the sewerage system. Conditions up until the mid-1970's were typified by a variety of practices for the treatment and disposal of hazardous wastes:

- Large industries tended to treat and dispose of their wastes to standards acceptable to relevant State government bodies. In some cases these standards were set on a case-by-case basis rather than as part of a well defined framework.
- Some co-disposal of hazardous wastes with domestic refuse was undertaken. This was sometimes deliberate and controlled, and in some cases was not controlled.
- The most common dedicated disposal practice was via lagoon systems, with retention of solids in the lagoon and loss of liquids by evaporation and infiltration.
- Instances of illegal disposal and uncontrolled disposal to landfill occurred.

In 1983, the AEC Report was published, entitled "Management and Disposal of Hazardous Industrial Wastes." It identified problems with the then existing situation and made recommendations on how these problems could be overcome. This report became the framework for the current hazardous waste management activities in Australia. The report identified the following goals:

- The establishment of adequate facilities, particularly a single national high temperature incinerator, for the destruction of chlorinated organic wastes.
- Establishment of required treatment facilities with a range of chemical, physical, and biological treatment processes and a controlled landfill for disposal of other hazardous wastes.
- Establishment of control systems to ensure that hazardous wastes are properly handled and disposed of, including a hazardous waste manifest system controlled by one body in each State, with all States adhering to a common classification system.
- Encouragement of waste minimization and recycling programs.
- Reduction of the existing stockpile of hazardous wastes, particularly the stable organochlorides, by ocean or overseas incineration if feasible.

At the time of the publication of the 1983 AEC Report, the information on the quantities and characteristics of hazardous wastes in Australia was poor. Since the publication, a number of States have undertaken additional surveys:

- 1983 - New South Wales State Pollution Control Commission; estimate of 60 ML/year (63,500 tons)* of industrial liquid waste generated in Sydney.
- 1984 - Survey by the Victorian Environment Protection Authority; estimate of 61 mL/year (64,500 tons) industrial wastes in Melbourne and 77 ML/year (81,400 tons) in Victoria.
- 1985 - Survey by the South Australian Waste Management Commission, from manifest records; 53.4 ML/year (56,400 tons) of industrial wastes.

The level of industrial activity in Australia is characterized by a high concentration of hazardous waste producing industries in Sydney and Melbourne. Since the publication of the 1983 AEC Report, there has been the development of the 1986 National Guidelines for the Management of Hazardous Wastes. This calls for the government implementation of these guidelines. Some of the key principles of this document are:

- The polluter pays principle should apply to all aspects of the management of hazardous wastes.
- Generators, transporters, storers, treaters, and disposers of hazardous wastes should be regulated and be required to conform with the regulatory standards.
- The classification system for hazardous wastes described in the guidelines should be applied nationally.
- A common transport manifest system should be implemented by waste management authorities.
- AEC should develop specific technical and environmental guidelines on site selection criteria for hazardous waste facilities.
- One national high temperature incinerator should be built.
- A national system for the exchange of industrial wastes should be established.
- Australian and overseas research and development on hazardous waste management should be monitored by AEC's Advisory Committee on Chemicals in the Environment.

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*ML/year = 1 x 10^6 liter/year.

Since the publication of these guidelines in November of 1986, the six Australian States have begun to more closely develop a single nationally coordinated approach to hazardous wastes.

In spite of numerous well prepared proposals, Australia to date has been unable to establish a high temperature incinerator. Concern by residents and some sections of public interest groups over the safety and public health aspects of incineration has forestalled the introduction of this component of the hazardous waste management system in Australia.

BELGIUM OVERVIEW

Belgium, as declared in their constitution in 1970, is divided into three regions: the Flemish Region, the Walloon (French-speaking) Region, and the Brussels Region. While a central parliament retains certain traditional authority in Belgium, environmental protection is among the powers delegated to the Regions.

The Flemish Public Waste Agency (known in Belgium as OVAM) was created by a decree on the management of waste enacted July 2, 1981. The agency has the authority to plan, regulate and establish facilities for the management of solid and hazardous waste for the Flemish Region of Belgium. The agency also supports some research and development of waste processing methods, and subsidizes new domestic waste treatment facilities such as incinerators. OVAM operates under the administrative control of the Minister of the Environment.

The work of OVAM in the field of hazardous waste management has included the development of accurate information on waste generation, treatment and disposal in the Flemish Region, and the preparation of a Hazardous Waste Management Plan. OVAM has recently been working to establish a series of integrated treatment and disposal facilities for the management of hazardous wastes, through a public/private corporation known as INDAVER. Further regulatory action designed to tighten the standards for treatment and disposal of hazardous wastes in the Region is expected.

Although more information was not available at the time, it is assumed that the Walloon Region and the Brussels Region of Belgium have an agency and programs similar to those in the Flemish Region.

CANADA OVERVIEW

The management of hazardous wastes in Canada is the responsibility of both the Federal government and the Provinces of Canada. The Federal government has the role of gathering and disemminating information, developing national guidelines, and conducting research, development, and demonstration activities. In addition, the Federal government has direct responsibility for the remediation of "Federal lands" including the Yukon and Northwest Territory and facilities of various Federal government departments such as Canadian Armed Forces bases, airports, and national parks. The mechanism for dealing with the management of hazardous wastes is the Canadian Council of Resources and Environment Ministers (CCREM). The development of a "national contingency fund" to respond to the release of hazardous substances is presently being addressed by the CCREM.

Within Canada, the remediation of contaminated lands and ground water, excluding Federally-controlled areas, is the direct responsibility of the provinces. Environment Canada, working with seven participating provinces, has initiated the "Waste Disposal Site Program" to respond to hazardous waste problems. This program consists of three major phases:

I. The identification of all operational and closed waste disposal sites, collection of available data, and ranking of sites.

II. Preliminary field assessments of all sites, validation of existing data, and collection of data to fill information gaps.

III. Detailed field assessments of sites to identify impacts and recommend remedial alternatives, if appropriate.

Phase I site investigation studies have been completed in all Canadian territories and provinces with the exception of Ontario, Quebec, and British Columbia, who are conducting independent studies. During Phase I, 9,292 waste disposal sites have been identified with 747 sites given a Priority 1 ranking. An additional 3,772 sites were identified in the Provinces of Ontario and Quebec. The total number is expected to grow as further effort is directed towards finding as yet unidentified sites.

In addition, a limited overview of ground water contamination throughout Canada has recently been completed. As a result, four sources of ground water contamination have been identified. These are:

1. Waste Containment and Disposal Operations;

2. Industrial Operations (unintentional releases);

3. Agricultural Activities; and

4. Management Conflicts (deficiencies in maintenance).

In response to the discovery of these abandoned hazardous waste sites, four classes of remedial alternatives have emerged. Indirect remedial measures, which do not eliminate the source or extent of contamination, may be all that is warranted. These interim measures may include purchasing contaminated properties or providing alternative water supplies to the area. Direct remedial measures are designed to fully rehabilitate contaminated properties which would involve both source control (removal) and plume control (treatment). Other actions may be necessary such as continued monitoring of affected areas. The fourth alternative available is no action.

At many sites, some form of action has been taken, including ground water monitoring or the recommendation or implementation of some type of remedial measure. Where leaking underground storage tanks have been found, leaks have been repaired and usually some form of product recovery system has been installed. At these sites, contaminated wells have either been replaced or an alternative water supply has been provided. It is noteworthy to mention, that either indirect or direct remedial measures have been undertaken or been proposed for the majority of the abandoned hazardous waste sites found in Canada.

DENMARK OVERVIEW

Denmark has established a complete system and set of procedures for the management of hazardous waste, including the following main components: legislation, a packing/transport system, a transfer station system, and a central treatment system (Kommunekemi). The three basic principles of this hazardous waste management system are: the obligation to give notification of the type and amount of waste produced to the municipal authorities, the obligation to deliver the waste to the municipal collection system, and the treatment of the waste at the central plant.

The administration of the Danish system is organized in a decentralized way, whereby local municipalities do the permitting and are responsible for the establishment of a collection system. There are no direct subsidies to enterprises for the treatment of hazardous waste and each delivery of hazardous waste to Kommunekemi is charged according to a price list. Special arrangements to facilitate the delivery of wastes do exist, however.

Municipalities may exempt industries from the duty to deliver hazardous waste to Kommunekemi if environmentally sound treatment of the waste is ensured. For example, in 1985, 91,198 tons of hazardous waste were treated at Kommunekemi, however in 1984, 23,750 tons of waste were granted exemptions.

The Kommunekemi facility is a publicly-owned and operated facility, although the corporate structure is like a share company, owned by all Danish municipalities. The incinerator plant accounts for Kommunekemi's largest treatment section. Wastes which cannot be treated at Kommunekemi such as cyanide-containing hardening salts, mercury, or PCB-containing solid wastes are deposited in West Germany in a salt mine.

In Denmark, the regional collection and transfer system is effective, along with control of the industrial hazardous waste stream. Cooperation between industry, the centralized management system, and the incineration facility has been successful. Like most other European countries, one of Denmark's major thrusts has been in research in the field of recycling and waste source reduction.

In the late 1970's, the identification of several abandoned contaminated sites prompted the enactment of an emergency law designed to address the legal and economic problems of such sites. Denmark is subdivided into 16 counties, each having an environmental agency. These counties were to report hazardous waste sites for which no principal responsible party could be found. In 1983, a law was enacted providing an equivalent of 100 million Deutsch Marks (DM) for the investigation and cleanup of these sites over a 10 year period. To date, 1,200 sites have been identified which require action. One hundred different sites are presently being investigated by County administrations, with 20 of these sites having remedial action on-going. Sites where human health or the quality of the ground water are threatened have top priority.

FEDERAL REPUBLIC OF GERMANY OVERVIEW

The Waste Disposal Act of the Federal Republic of Germany passed in 1972 includes regulations for defining hazardous or special waste, guidelines for waste disposal, liability for disposal, regional planning for disposal, licensing of facilities, trip tickets, licensing for transport, and waste import. More recent acts provide regulations for transportation safety, data collection, waste collection, recycling and burning of oil, and special regulations which protect against water pollution.

State governments are responsible for implementing and enforcing the requirements of the Waste Disposal Act. Most states are equipped with an Environmental Protection Agency.

Total waste management is performed under the so-called "polluter pays principle" which means the generator of waste has to pay full cost for waste disposal. Subsidies are sometimes given for research studies and investigations in the field of special waste disposal.

Commercial hazardous waste management begins with onsite storage. The materials are then transported to treatment or disposal plants. In some cases such as in Bavaria, special collection points have been built to reduce transport distances and to collect sufficient quantities of waste to minimize the number of trips. Such collection points are sometimes combined with pretreatment facilities for sedimentation.

Land incineration systems in the Federal Republic of Germany mostly use the rotary kiln. Seventeen incinerator facilities are available in the Federal Republic of Germany, as well as 23 physical/chemical treatment plants. One large treatment center is the Gesellschaft Zur Beseitigung von Sondermiill in Bayern mbH (GSB), the central processing plant in Bavaria. It is a not-for-profit company with facilities for wastewater purification, physico-chemical treatment, incineration and landfill.

It is estimated that 30,000 tons of special waste per year is incinerated onboard ships in the North Sea, half of it highly-chlorinated material. PCBs, however, are not allowed to be burned at sea.

A certain amount of hazardous waste makes its way in and out of the Country. In 1982, for example, special waste generation in the Federal Republic of Germany was 4.5 million tons. About 40,000 tons were imported from Switzerland, the Netherlands, France, and Belgium. About 180,000 tons were exported, including 140,000 tons into the GDR and 40,000 tons into EEC countries (Switzerland and Austria).

One underground mine disposal facility is Herfa Neurode, in Kassel, located in an abandoned salt mine. About 45,000 tons of imported and domestic special waste are disposed of here each year. Storage in the caves of the mine is manifested, so that special waste can be excavated later on for recycling.

There is only a small capacity remaining for landfilling of hazardous waste in Germany. German State Ministers for Environmental Affairs have, therefore, recently decided that each State of the Federal Republic of Germany should provide sufficient disposal capacity both for burning and for land disposal.

Since 1984, the research and development of remedial technologies has been a part of a program for environmental research funded by the Ministry for Research and Technology. Remedial technology development has been aimed at two general areas: 1) the prevention of spread of soil and ground water contamination; and 2) the elimination or reduction of soil and ground water contamination. These areas are of particular concern since greater than 70 percent of the drinking water in the Federal Republic of Germany is from ground water.

In addition, special waste exchange markets have been operated for over 10 years by German industry which have helped to minimize or to avoid unnecessary waste generation. Within the last few years, no major violation in special waste management has been found in the Federal Republic of Germany.

However, by the end of 1985, 35,000 suspicious sites had been identified by State authorities including 30,000 abandoned waste disposal sites and 5,000 contaminated industrial sites. It is estimated that 10 percent (3,000) of the abandoned waste disposal sites and 50 percent (2,500) of the industrial sites would be classified as environmentally dangerous. No special program is presently available in the Federal Republic of Germany for remedial actions to be taken at these sites.

New legislation outlining the economics of waste markets, and new technologies for waste reduction have been drafted with an improvement of the situation in special waste management being expected. New technologies are also under investigation for the immobilization of hazardous components and for the remediation of abandoned sites. Waste disposal plants should also be improved further to attain the higher technical standards developed in underground control for landfills and in flue gas cleaning for incinerators.

The waste disposal program in Bavaria, with several collection points, is a good example of a system that works. Their philosophy, given by Dr.-Ing. Gerhard Sierig of Berliner Stadtreinigungsbetriebe, is "A high standard of living coincides with the high quality of the environment - in the air, soil and water. It can only be preserved when the amount of waste is reduced by new technology and when waste disposal technology is improved further."

FRANCE OVERVIEW

A law dated July 15, 1975 "makes it the obligation of each and every person generating or possessing wastes to ensure their disposal in such a way as to avoid adversely affecting human health and the environment." The new law prompted the construction of treatment centers, an end to unauthorized dumping, new regulations, and the development of more elaborate techniques for collecting, transporting and storing wastes. Several texts have been appended to the above law. They govern classified establishments (1976), control of chemicals (1977), treatment of used oil (1979), industrial waste landfills (1980) incineration (1983), and the importation of toxic wastes (1983).

The National Agency for Waste Recovery and Disposal (ANRED) has come to play a major role in centralizing information and promoting new treatment and recovery techniques in France. At the same time, ANRED serves an equally crucial role in the French economy by electing to support those projects in which a national economic interest is present.

Government authorities are responsible for setting and enforcing discharge standards. Authorities are presently in the process of drawing up an invoice system to keep track of special (hazardous) wastes from source to destination. Transportation and collection of waste, as well as all disposal and recycling facilities are privately run. Their success is to be determined by the laws of economics.

The Basin authorities in France are also important waste management agencies. There are six such basins responsible for water management and pollution control. The Basin authorities generate significant income through the assessment of fees for drinking water and water pollution discharges. The funds are redistributed to finance pollution control within the basin and support innovative industrial waste stream management at ANRED.

Today there are a wide variety of waste collection and transport firms grouped together in professional associations, such as the National Union of Liquid Waste Collectors. Many such companies also do industrial cleaning and work at contaminated sites. At this time, there is no official authority for these activities, with the exception of one in northern France.

As of February 1984, wastes were treated as follows:

Various treatment processes (incineration, physicochemical, etc.)	500,000 to 600,000 ton/yr
Special landfills	500,000 ton/yr
Special treatment in-house	300,000 ton/yr
Upgrading (recycling)	200,000 ton/yr
Incineration at sea	11,000 ton/yr
Exported (4,000 tons to salt mines in FRG)	10,000 ton/yr

Capacity in the incinerators has now reached saturation point. To ease the pressure on the incinerators, a few cement factories (five in 1984) have been authorized to receive certain special wastes, with about 20,000 tons being removed at present. In 1986 there were 13 landfills and 10 incinerators, three of which can treat only liquid wastes while the other seven can treat solids, liquids and pastes.

Five treatment centers, with a total capacity of 250,000 ton/yr are now in service. The techniques used include processes for treating specific special wastes (phenolated water, cuproammoniacal effluents) and vary from one center to another. The most common processes are neutralization, chromium removal, cyanide removal, and sludge fixing. The nature of physical-chemical treatments depend on the nature of the waste to be disposed of, and by extension, the manufacturing activity. Accordingly, the level of innovation in this area is high and a great deal of laboratory research is carried out. Discharge-related problems still remain to be solved.

Today there are ten centers in France for treating oil and solvents, with a total capacity of 100,000 ton/yr. Eighteen centers, with a total of 50,000 ton/yr specialize in waste solvent recovery. Small, highly specialized firms exist for the recovery and upgrading of wastes such as mercury, silver, copper, chromium, nickel and cadmium. With this number of highly diversified firms, France makes it possible for all manufacturers to comply with relevant legislation for which government authorities are responsible.

Many aspects of hazardous waste management in France are effective and have been successful. Processes for neutralization, and chromium and cyanide removal, are now well under control with discharge standards met without any particular difficulty. The French also have a good understanding of incineration including that of solid and spadable wastes.

National inventories of abandoned industrial waste dumps were carried out at the end of the 1970s. While these inventories showed the existence of 100 such dumps, they were far from complete, lacking risk assessments and the nature and origin of the wastes involved. Over the past 3 years, about 53 operations to decontaminate soil have been conducted. They include a diagnosis, removal of the most highly toxic wastes, and onsite treatment (solidification). A technical assistance team, SATED (Service d'Assistance Technique aux Depots de Dechets) provided by ANRED, is in charge of the national inventory of wastedumps. Their main activity is providing technical assistance to industrial firms or local authorities who are having problems eliminating old dumps that pose a health hazard.

Although measures seem to be working well, there is still room for improvement in France with regards to the management of hazardous waste. Treatment centers are striving to conceptualize and develop processes for wastes not yet properly treated and are working to improve existing treatment methods in order to better comply with discharge standards that they believe will become more stringent in the future. Also in the near future, France will be in need of a number of new landfills approved for the disposal of hazardous waste, as existing landfills are reaching their capacity.

INDIA OVERVIEW

India, unlike the other countries reviewed in this report, is a developing country stricken by poverty and over-population. It may be India's long history of accepting poor water quality caused by bacteria and the subsequent expectation of large mortality and morbidity rates, that hazardous waste has been given little consideration. At this time in India, economic development may be a higher priority than a clean environment.

Although India is a developing country, it is not technologically unsophisticated. It has about 140 centers of higher learning that graduate the "third largest scientific and engineering manpower in the world", according to an Indian embassy spokesman. It is in these higher learning centers that research is being carried out in the field of hazardous waste.

Health and safety standards were first required in India through the Factory Act of 1948. Although this act has since been amended, it is still outdated today, geared more towards mechanical industries (like textiles) than chemical plants. Also at this time, no chemical exposure limits had been set. It is unclear whether the standards have been revised since then. Other legislation includes the Pesticide Act of 1968, the Water Act of 1974, and the Air Act of 1982.

India has a Department of the Environment, analagous to the Environmental Protection Agency in the United States, but it is very thinly staffed and enforcement is minimal. The State government of Madhya Pradesh, India's largest State (of which Bhopal is the capital), has 15 factory inspectors who monitor more than 8,000 plants.

Hazardous waste management has so far received perfunctory attention in India. Quantitative information on a countrywide basis concerning the nature and quantities of hazardous wastes from chemical industries is not available. A sample survey, commissioned by the Department of Environment, on selected chemical industries has revealed that as much as 22 percent of solid wastes are hazardous in nature. These are usually disposed in nearby, lowlying areas without proper treatment and protection measures.

India's current laws and regulations do not adequately provide for safe handling and secured disposal of hazardous substances. An appropriate Act and institutional mechanism must be instituted to regulate disposal of these substances. Some steps that have recently been taken include industrial location policy, procedure of environmental clearance for project approval, formulation of industry-specific standards, and fiscal incentives for pollution control. An integrated approach in terms of policy and regulatory and promotional measures is recommended for coping with the mounting problems of hazardous waste management.

JAPAN OVERVIEW

The first National Control System in Japan was established with the enactment of the Japanese Waste Disposal and Public Cleansing Law (No. 37) on December 25, 1970. The Law consists of five major chapters: General Regulations; Municipal Wastes; Industrial Wastes; Miscellaneous Regulations, and Penal Regulations.

As to the responsibility for industrial waste disposal, the Waste Disposal Law provides that enterprises must treat their industrial waste themselves. Japanese enterpreneurs usually recommend in-house treatment of hazardous waste under the guidance of cities, towns and villages, as well as prefectures. Each perfecture has an antipollution measure control council in which serves as a place to exchange information on industrial waste disposal. Recently, efforts have been made towards establishing joint treatment operations through such consultative organizations.

Some industries in Japan are considering organizing an "antipollution measures committee," to work out antipollution policies and to establish a nationwide treatment program. Industries such as the steel, tire, and electrical appliances industry hope to promote improved industrial waste measures through such an organization.

Guidance and supervision over entrepreneurs and waste treatment contractors and, on-the-spot inspections are a major part of each prefecture's industrial waste administration. As of April 1985, the environmental sanitation inspectors who perform this duty numbered 3,000, a relatively small number compared with the number of enterpreneurs and treatment contractors. It has, therefore, been difficult to conduct adequate guidance and supervision over these activities.

As a result, many instances of illegal industrial waste dumping under the Waste Disposal and Public Cleansing Law occur each year. In 1980, 5,456 cases of illegal disposal were reported throughout the country, 89 percent from industrial solid wastes. Unfortunately, the number of cases is increasing. In 1983, 5,983 cases of illegal disposal were reported. The primary reason for illegal dumping has been the difficulty experienced by individual entrepreneurs in finding available disposal sites.

Hazardous wastes in Japan are supposed to be pretreated or solidified in concrete before being deposited in strictly-controlled landfills. Special treatments are also available, such as cyanide decomposition and disposal at sea. It is estimated that roughly 85 to 90 percent of final disposal is landfill disposal while 10 to 15 percent is subject to ocean dumping. Presently, there are no facilities to treat PCBs, since the treatment method for PCBs is still under investigation. Transport of hazardous wastes to other countries for disposal does not occur because it would involve travel by sea.

Future expectations for hazardous waste management in Japan include the enforcement of statutory regulations. The general regional developmental plans will include a waste treatment plant project. Also, the number of environmental and sanitation professionals will be increasing to ensure better supervision and a better understanding of the different treatment techniques available. Further research and development will be needed in addition to the training and education of qualified individuals. Other major industrial waste management priorities include volume reduction and the promotion of recycling.

THE NETHERLANDS OVERVIEW

In the Netherlands there are many different types of industries and, in this densely-populated country, toxic waste is produced in many places. To manage these wastes, a legislative framework of acts exists specifically created for the protection of the environment. The requirements for licensing, the limited periods for which permits are granted, and the conditions attached to permits encourage innovative ways of preventing hazardous waste production. In the last 20 years, many industries exerting high impact on the environment have been reorganized to reduce this impact. Use of materials which can produce toxic waste such as PCBs or asbestos, is expressly forbidden or allowed only under stringent conditions.

Hazardous waste has been landfilled in the past. Advances in thermal treatment technology allowed a rotary kiln incinerator to be started in 1973, with a new one that came on-line in 1986. In total, about 110,000 tons of the generated chemical (hazardous) waste are incinerated per year, of which 40,000 tons are incinerated in rotary kilns, 40,000 tons are co-incinerated with domestic waste, 2,000 tons are incinerated at sea, and the remainder is exported. At present, 80 percent of the hazardous waste to be landfilled is exported. Receiving countries include Belguim, United Kingdom, France, the FRG, and the GDR. Of the 12,000 tons of chemical waste landfilled in the Netherlands, most is subject to co-disposal with municipal waste. The Netherlands hope to eventually be self-supporting following the construction of another rotary kiln incinerator and a controlled landfill by AVR-Chemie.

The basic facilities for final disposal of chemical waste in the Netherlands are centralized. AVR-Chemie is the central facility and is jointly owned by the central government (10 percent), the city of Rotterdam (45 percent), and eight multi-nationals (45 percent). In addition, there are approximately 40 privately-owned small firms who specialize in a certain part of the hazardous waste disposal market.

In January 1983, the Interim Soil Cleanup Act was enacted in the Netherlands. Investigations under this program have identified about 1,600 cases of serious soil contamination which require remedial action. Research into the areas of site-investigation and remediation required for the implementation of this act is taking place under various national programs at institutions such as the prestigious Netherlands Organization for Applied Scientific Research (TNO)/Division of Technology for Society. Financing the cleanup of an abandoned site goes by the "polluter pays" principle, except when the polluting firm cannot be found. In this case, the national government pays 90 percent of the cleanup costs while the local authorities pay the remaining 10 percent.

Since the implementation of the Chemical Waste Act in 1979, chemical waste has become easier to trace, particularly by the central government. Enforcement, however, has not been as strict as it could have been due to a lack of efficient division of responsibility between provincial and municipal authorities. Some corrupt companies have taken advantage of this disorganization.

Research into both clean and environmentally acceptable technologies will be continued including a survey of modified processes and modes of production, and the use of alternative raw materials. Research findings will be communicated to companies individually, via an information center set up by industry, through the central government, and through the chambers of commerce and industry.

SWEDEN OVERVIEW

Hazardous waste management in Sweden is regulated by a number of laws, ordinances and regulations which exist at various levels throughout their society. The "Ordinance on Hazardous Waste" introduced in 1975, was the first comprehensive piece of legislation to deal directly with the managing of hazardous wastes. This ordinance regulates the generation, storage, transport, and disposal of both household and industrial hazardous wastes.

In recent years, the Swedish population has become increasingly more urbane and concentrated with approximately 70 percent of the population now living in cities. The quantities of municipal and hazardous waste generated by the growing urbanized population has created new problems for the government in the area of hazardous waste management.

In the early 1980's, it was decided that some type of a centralized treatment facility was necessary to properly treat and dispose of the rapidly increasing hazardous waste stream in Sweden.

In 1983, the State-owned SAKAB incineration facility, a central treatment facility designed to meet this need came into operation. Federal laws were created requiring local jurisdiction over the collection and transport of both household and industrial hazardous wastes within municipalities to the facility for disposal. The entire system is owned and operated by public entities, thus eliminating the regulatory difficulties which often accompany private sector involvement. The SAKAB facility has been designated as the sole repository and treatment facility for hazardous wastes in Sweden. SAKAB also operates a nearby landfill for waste that cannot be incinerated, as well as for ash and slag from the incinerator itself.

The facility receives 35,000 barrels/year of hazardous waste for disposal. Approximately 4 to 5 barrels of waste are incinerated each hour. The waste goes through a preheating area, initially fuelled with oil, to the rotary kiln itself, to a secondary gas combustion chamber, through the boiler tubes, through a scrubber, and finally an electrostatic precipitator. The most recent analysis indicates that less than 0.2 grams of dioxin are produced annually by the facility. The operators believe that this is the most dioxin-analyzed facility in the world.

The landfill at SAKAB is actually above-ground. The first level consists of soil, covered with gravel, followed by asphalt and a liquid sealant. At this point, the site is ready to receive ash and slag. Following the addition of the ash and slag, a portable canopy is placed over the top. Soil and sand is then applied to the canopy and the entire area is grass seeded.

Swedish authorities acknowledge that uncontrolled hazardous waste sites can occur however well laws and regulations are designed. The incidents of uncontrolled releases of hazardous substances to the environment, which reportedly have occurred only in small quantities in Sweden, do have the capacity to cause serious damage to the environment. Authorities feel that uncontrolled waste management can be minimized with increased control, with better resources for the supervisory body, and by managing wastes in a service-minded manner and at the "right" cost for the market. The main problem with respect to inadequacies in supervision and control is the lack of personnel in the supervisory authorities. This aside, cooperation between authorities and waste-generating industries has been positive and overall, hazardous waste treatment systems in Sweden are very efficient.

At present, a nationwide inventory of old landfills is being carried out by the supervisory authority (the National Swedish Environment Protection Board, in conjunction with the Swedish Association of Local Authorities) to determine which landfills contain hazardous wastes. Sites which have been closed have been assessed, and in some cases, decontaminated. However, a regulatory mechanism providing for the restoration of abandoned hazardous waste sites in Sweden has yet to be developed.

UNITED KINGDOM OVERVIEW

The United Kingdom is unique to Europe in the sense that hazardous waste management practices center primarily around local authorities. The central government does have some responsibilities as defined in the Control of Pollution Act of 1974, however, the major role of the central government is the development of guidance documents for the handling and disposal of hazardous wastes. The central government agency for environmental matters in the United Kingdom is the Department of the Environment, which receives its technical support through the Harwell Laboratory. A prestigious British institution, the Harwell Laboratory has its sole activities in the development of waste management technologies.

A negative impact resulting from the decentralization of waste management practices in the United Kingdom is that each local government and regulatory agency must maintain the necessary expertise to deal with all aspects of hazardous waste management. Such a system often results in a lack of uniformity of environmental regulation and application of environmental standards.

The United Kingdom also differs markedly from other European countries in the strong emphasis that it places on government control of land use. For example, the construction of a hazardous waste disposal facility requires approval from a local land planning board before it can be built. Licensing is then required through the Local Waste Disposal Authority who may reject an application based on indications that a threat to public health is posed by the facility. The authority also sets conditions on the license controlling discharges, which center on the premise that "hazardous substance releases to the environment must be limited to the amount which will not exceed the capacity of the receptor to absorb the substance with the occurrence of harmful effects." The Regional Water Authority then has the right to reject a license if necessary to prevent problems of water pollution.

The presence of these strict land-use controls has been cited as a reason for the lack of major problems with abandoned contaminated hazardous waste sites in the United Kingdom. By requiring planning and approval for industrial and all other land uses for many years, the United Kingdom has avoided the creation of unknown and unapproved disposal sites of the sort that have caused problems in the United States.

The United Kingdom does not have a problem with landfill sites on the scale reported in some other countries. A preliminary study conducted by the Institute of Geological Sciences suggested that, of 2,500 operational landfills in 1971, only 50 appear to have the potential for causing ground or surface water contamination. Consideration here must also be given to the unique geography and geology of the United Kingdom, where no area is more than 70 miles from the sea, and many aquifers receiving landfill leachate are naturally brackish and unusable for human consumption.

Co-disposal of hazardous wastes is the technology of choice in Great Britain and is institutionally supported by the Department of the Environment and the Harwell Laboratory. Proponents of the technology feel that the co-disposal of liquid industrial wastes with domestic solid waste has minimized, or better yet, eliminated all the negative environmental impacts associated with the disposal of industrial liquids alone. They believe household waste has the capacity to attenuate the leaching of polluting constituents from the industrial waste and aid biodegradation. The British argue that their co-disposal practices are scientifically based and will not create future ground water problems. In contrast, the United States does not allow this technology, due to past difficulties with co-disposal sites.

SECTION 3

INTERNATIONAL TECHNOLOGY FACT SHEETS

The following pages present the Fact Sheets developed for each international technology reviewed. The Fact Sheets summarize pertinent information available from the literature or interviews.

As shown on the Fact Sheets, limited information is presently available for many technologies. Often, technical articles or interviews provided only certain information. In addition, many technologies have not been extensively demonstrated in field trials, and certain information describing costs, limitations and performance have not yet been developed.

INTERNATIONAL TECHNOLOGY FACT SHEET

Process: Ion Exchange on Cross-linked Casein for Cr^{6+} Removal

Type of Treatment: Chemical

Country: Australia

Institution/Contact: Martin R. Houchin
Australia's Commonwealth Scientific &
Industrial Research Organization
Dr. George Winter
Univ. of Melbourne in Parkville, Victoria

Function: This process removes and recovers Cr^{6+} from waste electroplating and wastewater solutions.

Description: Acid solutions containing Cr^{6+}, Cr^{3+}, Zn^{2+}, and Cd^{2+} were passed through an ion exchange column containing 35 kg of +60 mesh casein. The casein had been previously cross linked using a 2% w/w formaldehyde solution. The anionic Cr^{6+} was adsorbed by the casein while the cationic Cr^{3+}, Zn^{2+}, and Cd^{2+} passed through the column. Cr^{6+} was eluted with ammonia. The casein was then washed, regenerated with sulfuric acid, and the cycle repeated. The eluant for each cycle consisted of the $(NH_4)_2CrO_4$ eluate from the preceding cycle with added ammonia.

Performance: The process is said to have shown promising results.

Limitations: None noted.

Economics: No information available.

Status: Research work on this process is continuing.

Recommendations: No further action. This technology has limited application to Superfund wastes.

Reference: Technical Insights. New Methods for Degrading/Detoxifying Chemical Wastes. Emerging Technologies No. 18. International Standard Book No. 0-914993-16-X, Library of Congress No. 85-51133. 1986.

INTERNATIONAL TECHNOLOGY FACT SHEET

Process: High-Temperature Slagging Kiln Incineration

Type of Treatment: Thermal

Country: Belgium

Institution/Contact: Rik Vanbrabant or Norbert Van de Voorde
Belgian Nuclear Research Center (SCK/CEN)
Waste Treatment Dept.
Bocretang 200
Mol, B-2400, Belguim
Tel.: 014 31 68 71

Function: High-temperature slagging incineration (HTSI) is designed for slagging of low-level radioactive waste materials, but also may be applied to wastes containing various types of hard-to-incinerate hazardous materials.

Description: At the incineration plant, the wastes are stored in the original package or in polyethylene bags after checking the packages for the presence of large metal pieces, explosives or high oxidation products. The waste is fed to a shredder by means of conveyors. A weighing device ensures that a suitable feed composition is achieved within given margin. The shredder reduces the waste to a size of 5 cm. The shredded waste falls onto a conveyor, to mixing bins which provides buffer storage volume and enables blending of solid waste with pastes or sludges before incineration. Screw feeders convey the blended waste from the mixing bins to the HTSI incinerator.

The waste is loaded into an annular space between the outer wall of the furnace and an inner cylinder, and is further pushed towards the combustion chamber. Then, the waste slides down to the outlet hole of the main combustion chamber and makes an inverted conical surface which delimits the combustion chamber at its lower part. The surface of the cone melts locally, forming a thin film of molten slag, flowing along the slope of the cone and leaving the main combustion chamber through the central outlet hole, together with the hot flue gas flow. The slag droplets fall into the granulator where they are quenched and burst to yield granules, while the combustion gas is channelled into the horizontal secondary combustion chamber. Here, oxidation reactions are completed.

Description (cont.):

Downstream of the secondary combustion chamber, the off-gases are cooled in a heat exchanger and by injection of water in an evaporative cooler. Dust is completely filtered out in classical bag filters followed by absolute HEPA-filters. In a scrubbing unit, the gaseous oxidation products are absorbed according to the stack emission limits. An off-gas blower keeps the whole installation in underpressure. Figure 1 shows a schematic of the process.

Performance: See Table 1.

TABLE 1. EXPERIMENTAL TEST RESULTS OF PCB INCINERATION

Mass flow rate of PCB	248 g/h
Air flow rate	1222 Nm^3/h
Off-gas flow rate	1272 Nm^3/h
% H_2O in off-gases	7.81%
% CO_2 in off-gases	8.47%
% N_2 in off-gases	75.91%
PCB mass flow rate in off-gases	0.55 mg/h
Residence time	1.92 sec
Combustion temperature	957°C
Lambda air factor	1.635
Off-gas O_2 concentration	7.8%
Combustion efficiency	99.99977%

Limitations: There have been some problems with phosphorous-containing wastes corroding the process equipment. The formation of NO_x has been limited by using a pure oxygen feed system. Also, this process is relatively expensive.

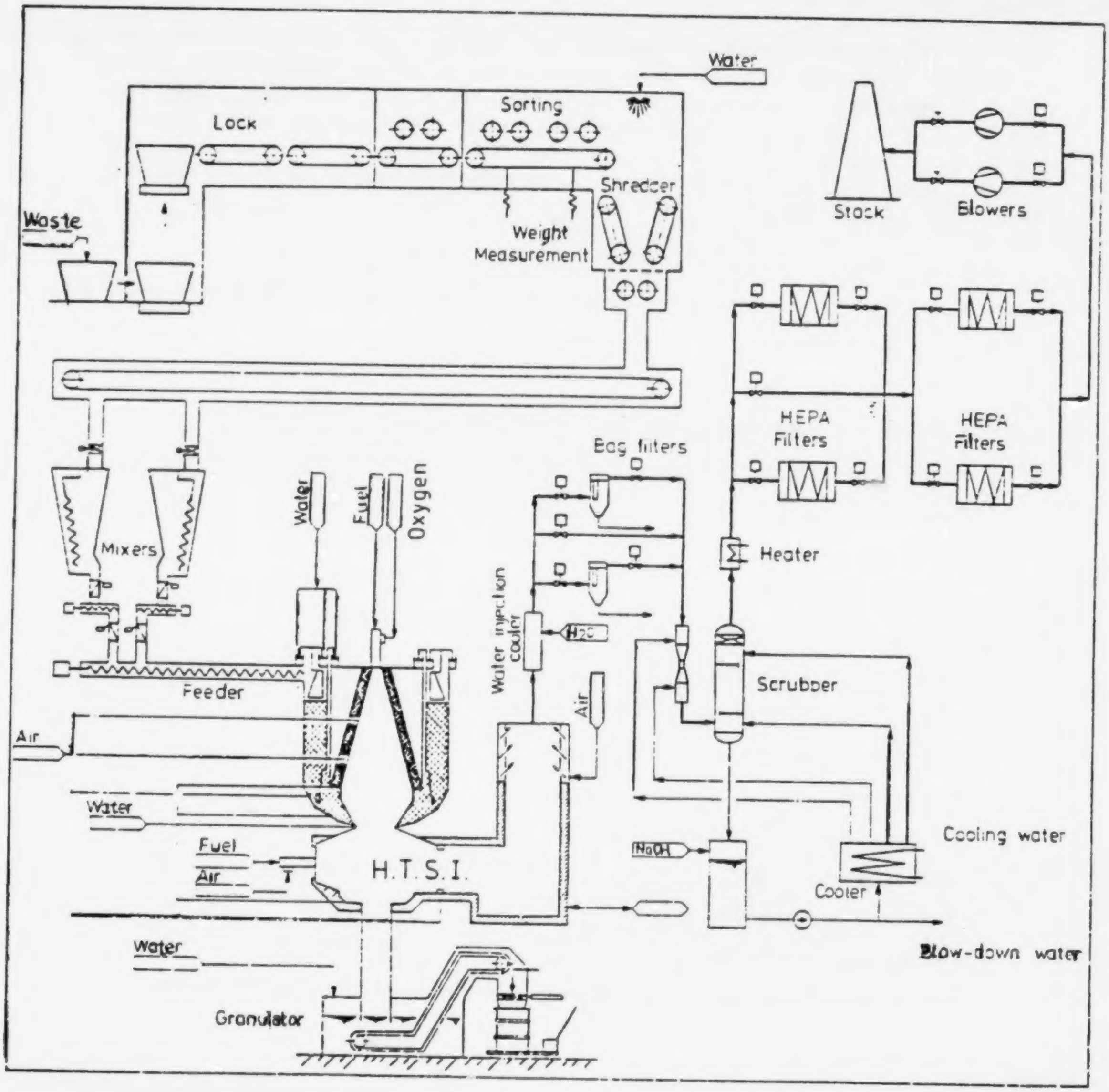

Water
Lock
Sorting
Stack
Blowers
Shredder
Waste
Weight Measurement
HEPA Filters
HEPA Filters
Bag filters
Water
Fuel
Oxygen
Mixers
Heater
Water injection cooler
H2O
Scrubber
Feeder
Air
Air
Water
Cooling water
Fuel
Air
H.T.S.I.
NaOH
Cooler
Blow-down water
Water
Granulator

Figure 1. Schematic of HTSI incineration process.

INTERNATIONAL TECHNOLOGY FACT SHEET (continued)

Economics: The process has been treating wastes at a cost of 20¢ to 30¢/kilogram. No economics are available on the new plant.

Status: The construction of the first demonstration plant was initiated in 1974. Since then, the plant has been operating on a regular basis handling about 5 tons of waste/week. This plant was originally built to treat radioactive waste, but test burns have been done on hazardous wastes and mixtures of hazardous and radioactive wastes. A larger-scale plant with a capacity to treat 100 ton/hour is expected to be operational in 1989. This technology is being marketed in the United States by IT of Tennessee, (615)690-3211.

Recommendations: While this technology is very effective at treating hazardous waste due to its high temperatures (approximately 1,000°C), it is also expensive. It is recommended that this technology could be practical for destroying hard-to-treat wastes such as PCBs. This technology is recommended for a site visit due to its departure from conventionably available processes and its imminent availability in the United States.

Reference: U.S. EPA. HWERL Proceedings: 2nd International Conference on New Frontiers for Hazardous Waste Management. Pittsburgh, PA. September 27-30, 1987.

INTERNATIONAL TECHNOLOGY FACT SHEET

Process: Synthetic Membrane Retrofit with Chain Excavator

Type of Treatment: Barrier

Country: Canada

Institution/Contact: K.A. Childs
Environment Canada
Ottawa, Ontario
K1A 1C8 Canada
Tel: (819) 997-2800

Function: Synthetic membrane and chain excavator for containment of soil.

Description: This system combines the capability of equipment used for excavating narrow trenches with a dispenser of synthetic flexible membrane materials. The synthetic barrier could be installed to a depth of 5 m using this system. The membrane material would be selected on the basis of having sufficient strength to withstand the stresses imposed at the time of installation, and its compatibility with the environment in which it will function. It is reported that the system allows for a rapid sequence of installation-excavation, membrane placement, and backfilling. Linear production rates up to 800 m/day are projected. The concept is shown in Figure 1.

Performance: Not demonstrated.

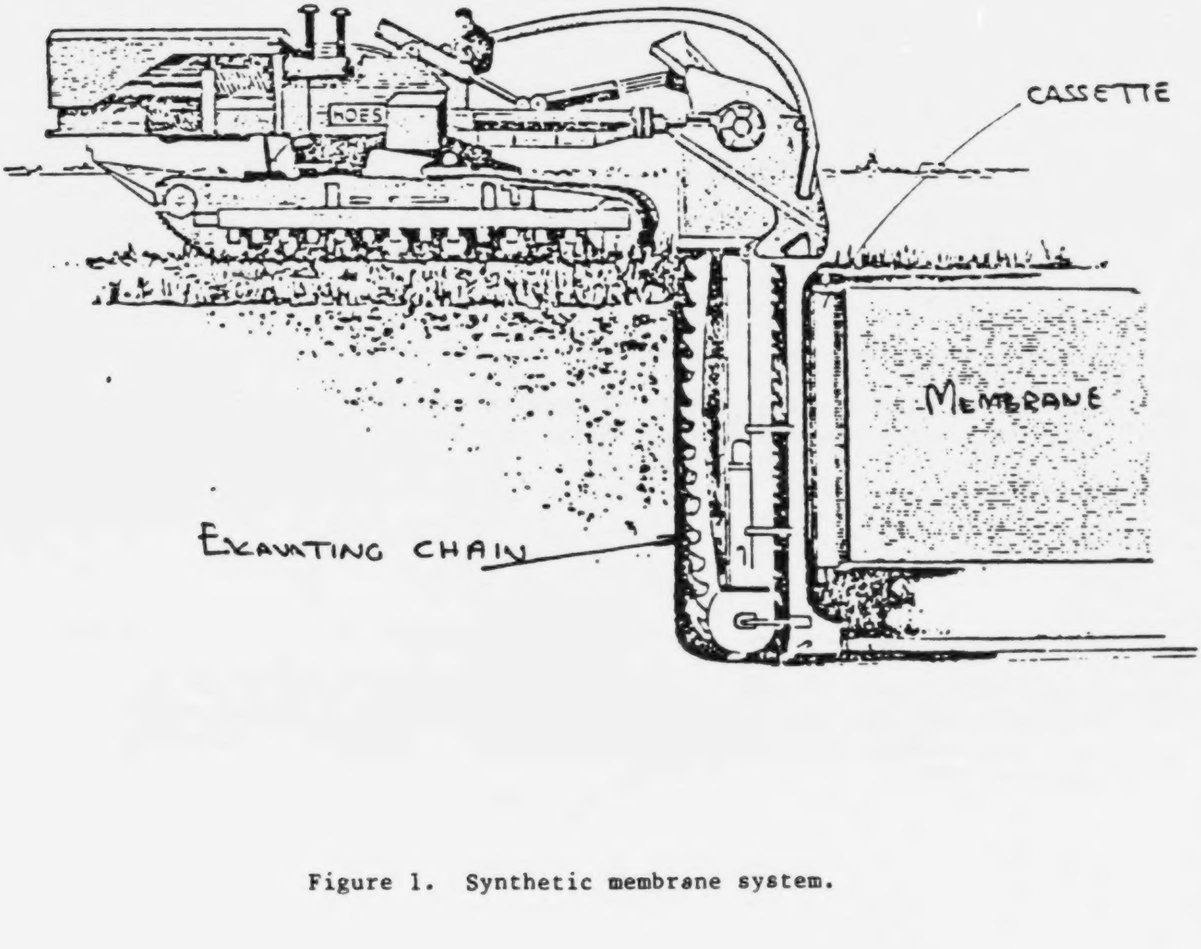

CASSETTE
MEMBRANE
EXCAVATING CHAIN
HOES

Figure 1. Synthetic membrane system.

INTERNATIONAL TECHNOLOGY FACT SHEET (continued)

Limitations: Data not available.

Economics: Data not available.

Status: Patents are currently being applied for.

Recommendations: Monitor the effects of chemical, biological, and mechanical stresses. Applicability would be based on economics and performance.

Reference: NATO/CCMS - Childs, K.A. Environment Canada. Pilot Study on Contaminated Land - Project D: Liquid Phase Management of Contaminated Land Including Horizontal & Vertical Barriers, Treatment, & Modeling. December 1983.

INTERNATIONAL TECHNOLOGY FACT SHEET

Process: "Kerfing" Cutting for Slurry Floor Installation

Type of Treatment: Barrier

Country: Canada

Institution/Contact: K.A. Childs
Environment Canada
Ottawa, Ontario
K1A 1C8 Canada
Tel: (819) 997-2800

Function: Cutting a void underground for installation of a slurry floor barrier.

Description: The method of bottom sealing by means of a slurry floor requires that intersecting voids be created under the area of concern. The voids are subsequently filled with a bentonite slurry. The voids are created by a "kerfing" system which is essentially a high-pressure, fluid-jet cutting tool. At normal operating pressures, the system will drive nozzles of 1 mm in diameter and, in most soils, will cut a slit 1 to 3 m long. Cutting rates up to several tens of cm/sec can be achieved. When used as a means of creating a cavity for bottom sealing, the jet is oriented to cut horizontally from the bottom of a previously drilled borehole. If the cutter is rotated without raising, a slit or thin disc is produced. If the cutter is raised, a column section will be formed (see Figure 1).

Performance: Information not available.

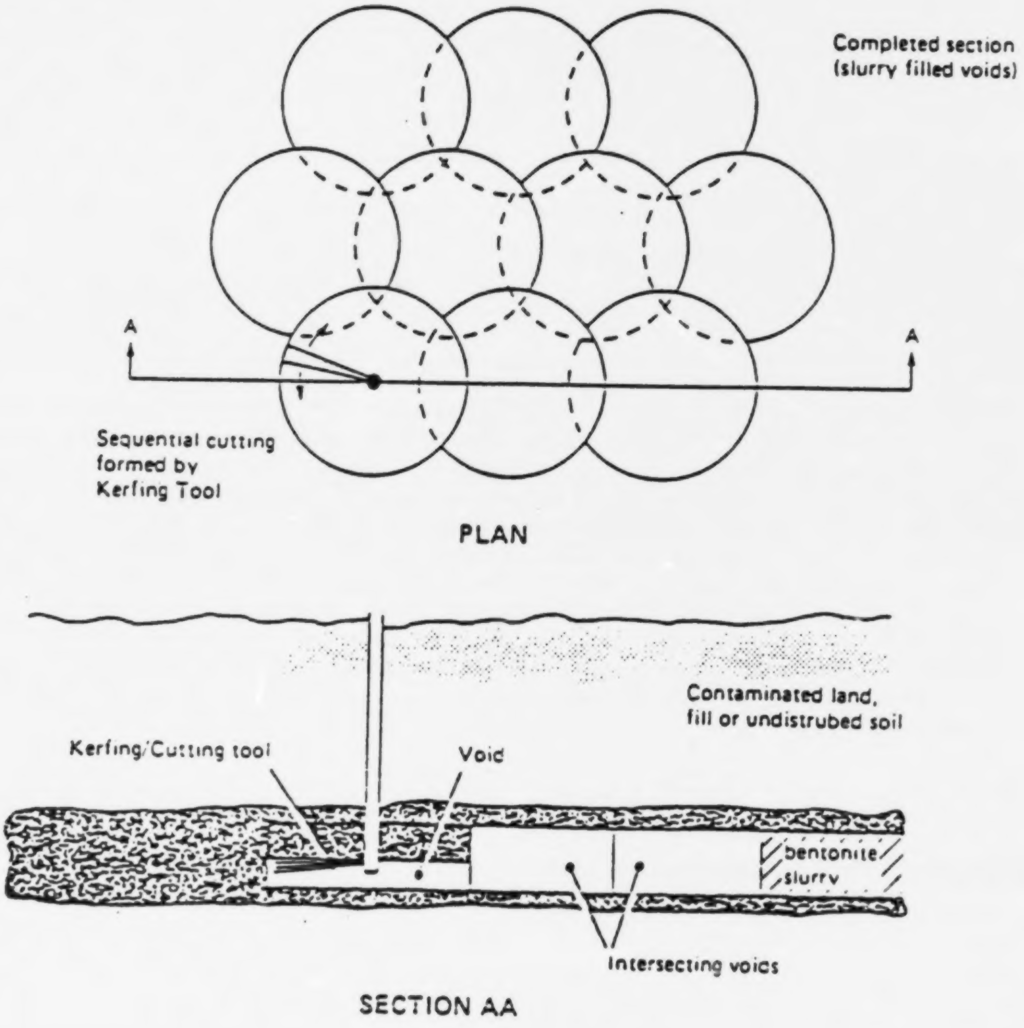

Completed section
(slurry filled voids)
A
A
Sequential cutting
formed by
Kerfing Tool
PLAN
Contaminated land,
fill or undistrubed soil
Kerfing/Cutting tool
Void
bentonite
slurry
Intersecting voids
SECTION AA

Figure 1. Under sealing by "kerfing".

Limitations: The soil or waste to be "cut" must not collapse or contain rocks or large boulders that would obstruct the void. There is no totally reliable way of making sure the void is undamaged.

Economics: Not known.

Status: Not known.

Recommendations: Monitor results of the use of this technique to determine effectiveness.

Reference: NATO/CCMS - Childs, K.A. Environment Canada. Pilot Study on Contaminated Land - Project D: Liquid Phase Management of Contaminated Land Including Horizontal & Vertical Barriers, Treatment, & Modeling. December 1983.

INTERNATIONAL TECHNOLOGY FACT SHEET

Process: Radiolytic Dechlorination of Polychlorinated Biphenyls

Type of Treatment: Physical/Chemical

Country: Canada

Institution/Contact: Mr. Stuart Iverson
also: Ajit Singh, Walter Kremers, and
Graham S. Bennett
Atomic Energy of Canada Ltd.
Whiteshell Nuclear Research Establishment
Pinawa, Manitoba R0E 1L0 Canada
Tel.: (204)753-2311

Function: Previous studies had reported that some chloro-organic compounds in alkaline isopropanol solutions were dechlorinated upon exposure to high energy radiation, via a chain reaction. This research was intended to study the application of the process to PCBs.

Description: Research was conducted using Aroclor 1254 (trichlorobenzene removed), drained capacitors, and PCB-contaminated soils. Solutions of PCBs in alkaline isopropanol and slurries of PCB-contaminated soils were prepared. Conditions were optimized to maximize G(-PCB) values (G = number of molecules formed or destroyed per 100 eV of energy absorbed). The solutions/slurries were subject to high-energy radiation with runs being conducted on 20-L solutions.

In the case of contaminated capicitors and transformers, the system involves the circulation of an organic solvent through the equipment from which the PCB/oils have been drained. The solvent picks up any PCBs that have migrated into the insulation or linings and then flows through a pipe that is looped through a gamma radiation field.

The effect of the radiation is to cause the chlorine to break off, leaving a biphenyl. As a result of another chemical reaction, the chlorine reacts to form potassium chloride, which can eventually be extracted from the solvent. The solvent is recycled through the system until the PCBs are removed from the equipment.

INTERNATIONAL TECHNOLOGY FACT SHEET (continued)

Performance: For 20-L runs using Aroclor 1254, the best value for G(-PCB) obtained was 80. For capacitors, values obtained of G(-PCB) were 25. The yields for PCB slurries were lower than the solutions by factors of 2 to 4.

Limitations: Advantages of radiolytic process:

1. The process is carried out in the absence of air, eliminating the formation of benzodifurans and dioxins.
2. On-line monitoring of the dechlorination process eliminates the possibility of incomplete detoxification.
3. Applicable to bulk PCBs, as well as PCB-contaminated material.

Economics: The estimated cost of PCB (54% chlorine) dechlorination is 890, 95 and 54 yen/kg, by photolysis, cobalt-60 radiolysis, and radiolysis with a 3-MeV accelerator, respectively (2 yen equals about $1 U.S.).

Status: Experimental - The radiolytic dechlorination process has been used successfully with drained capacitors containing adsorbed PCBs, as well as soil contaminated with PCBs. The process is likely to be relevant in industrial applications.

Recommendations: Monitor the results.

Reference: U.S. EPA HWERL. Proceedings: International Conference on New Frontiers for Hazardous Waste Management. September 15 - 18, 1985 Pittsburgh, PA. Co-sponsored by NUS. EPA/600/9-85/025. September, 1985.

INTERNATIONAL TECHNOLOGY FACT SHEET

Process: DeVoe-Holbein Extraction Using Vitrokele® Compositions

Type of Treatment: Physical/Chemical

Country: Canada

Institution/Contact: Dr. I. W. DeVoe and Dr. B. E. Holbein
DeVoe-Holbein, Inc., Canada

Function: DeVoe and Holbein developed a series of "metal-loving" synthetic molecules for the selective extraction of certain metals from solution.

Description: This process is analogous to ion exchange. These steps are followed:

1. Place the DeVoe-Holbein (DH) composition in a cylindrical glass column.
2. Pass the metal-containing solution through the column.
3. Remove the specific metal for which the DH composition was designed.
4. Divert the flow of water to a second identical column once the composition in the first column is saturated. Regenerate the first column with a solution that releases large concentrations of the metal from the composition.
5. Recondition the metal-free composition with a second solution, thus completing the recycling and readying the first column for reuse.

DeVoe-Holbein Inc. reports the compositions or compounds, trademarked Vitrokele®, meet the following criteria:

1. The ability to capture virtually all of a specific, target metal, even low concentrations, and with many other competing metals.
2. The ability to withstand harsh physical and chemical treatment without losing structural or functional integrity.
3. The ability to allow easy displacement of the metal, permitting metal concentration, high volume reduction, reuse of the composition and, in some cases, reuse of the captured metal.

Description (cont.):

4. The ability to capture substantial quantities of metal per unit of composition while maintaining high capture efficiency.

5. The freedom from toxicity, i.e., it should not add trace toxic components to the solution from which the metal is being captured.

6. The capability for being produced at a low cost, enhanced further by regenerability.

Performance: The process reportedly has been shown to be so selective that it is possible to remove only iron from a solution as complex as sea water. The process has been reported to achieve capture efficiencies of 99.5 percent or greater for zinc, nickel, copper, chromium (III and VI), silver, and mercury in various solutions.

Limitations: Recent tests have indicated that low capacity and selectivity may represent severe limitations for many applications.

Economics: A 4 gpm module costs $25,000, including 3.5 ft^3 of Vitrokele®. Operating costs are almost trivial according to a company spokesman. No special training is required of the operator. However, it appears that capital costs can be appreciable for many applications, due primarily to low capacity.

Status: Several standard modules in sizes that can accommodate 1 gpm up to 100 gpm are offered commercially. Bed sizes of standard modules run from 0.9 ft^3 up to 88 ft^3. The technology received U.S. Patent No. 4,530,963, and has a number of patents pending throughout the world.

Recommendations: No further action recommended.

Reference: Technical Insights. New Methods for Degrading/Detoxifying Chemical Wastes. Emerging Technologies No. 18. Int'l Standard Book Number 0-914 993-16-X, Lib of Congress No. 85-51133. 1986.

INTERNATIONAL TECHNOLOGY FACT SHEET

Process: Field Demonstration of Physical/Chemical Treatment of Groundwater at the Ville Mercier Waste Site

Type of Treatment: Physical/Chemical

Country: Canada

Institution/Contact: Mr. J. Schmidt
Head, Physical Chemical Processes Section
Wastewater Technology Centre
Environment Canada
P.O. Box 5050
Burlington, Ontario, Canada L7R 4A6
Tel.: (416) 336-4541

Function: Rehabilitation of aquifer providing potable water needs of Ville Mercier, selected as NATO/CCMS Pilot Study in March 1987.

Description: The NATO/CCMS Pilot Study at a hazardous waste site near Ville Mercier will evaluate the performance of an existing aquifer treatment system and any improvements instituted during the study period. Ground water contamination is largely organic in nature. Levels as indicated in the March 1987 NATO/CCMS Pilot Study Report are shown in Table 1 below.

TABLE 1. TOXIC ORGANIC COMPOUNDS IN RAW GROUND WATER - MERCIER, QUEBEC

Contaminants	Concentration ranges* (ug/L)
Total phenols	200 - 1,000
Dichlorophenol	3 - 32
Pentachlorophenol	4 - 54
1,2-Dichloroethylene	10 - 139
Trichloroethylene	20 - 104
1,2-Dichloroethane	76 - 164
1,1,1-Trichloroethane	23 - 200
Chloroform	52 - 60
Chlorobenzene	2 - 12

*Minimum and maximum concentrations observed from composite samples collected during pumping tests in the Winter of 1982.

Description (cont.):

A program to rehabilitate the aquifer was started by the Government of Quebec in 1981. The liquid material which was stored in a lagoon at the site was first removed (incineration, landfill) in order to prevent additional contamination of the ground water. Following this, contracts were awarded to develop a purge-well system and to design and construct a ground water treatment facility.

The pumping system consists of three extraction wells located a few hundred meters downstream of the hazardous waste dump site. These wells create a cone of depression into which contaminated ground water is drawn.

The processes considered for organics removal were oxidation, catalytic oxidation, air stripping, and carbon adsorption. Air stripping and activated carbon were chosen. Based on laboratory tests, generally satisfactory removals were obtained; however, for dichloroethane and trichloroethane, only 60 percent removal was achieved with air stripping. With activated carbon, 99 percent removals were achieved.

The wastewater also contained iron and manganese, suspended solids, and some oil and grease. Therefore, pretreatment prior to the activated carbon was required. The unit operations selected were coagulation and flocculation, followed by sedimentation and sand filtration. Both the pumping system and the treatment system were put into service in July 1984. Treated ground water is discharged into a small creek that flows into the Esturgeon River. A process diagram of the ground water treatment facility is shown in Figure 1.

The ground water treatment facility was designed to meet the following effluent objectives:

Contaminant	Effluent concentration objective
Phenols	2.0 ug/L
1,1,2-Trichloroethylene	4.5 ug/L
1,1,1-Trichloroethane	33.0 ug/L
1,2-Dichloroethane	50.0 ug/L
Polychlorinated biphenyls (PCB)	0.01 ug/L
Iron	0.3 mg/L
Manganese	0.05 mg/L

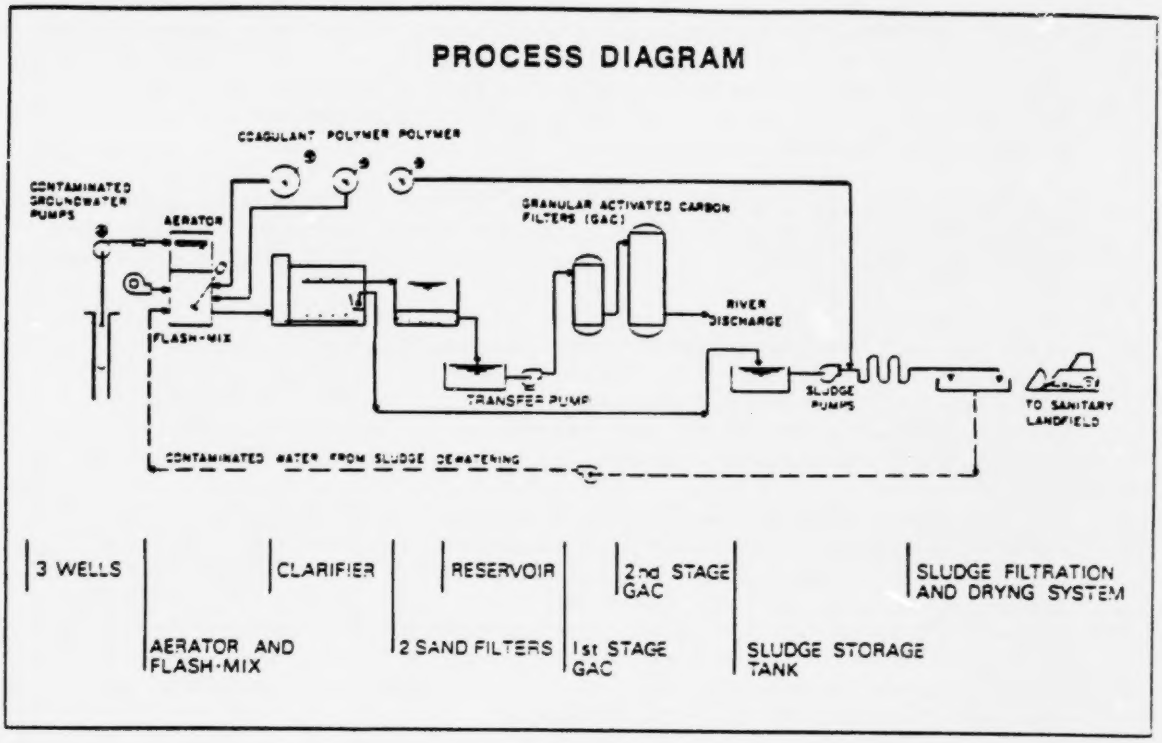

PROCESS DIAGRAM
COAGULANT POLYMER POLYMER
CONTAMINATED GROUNDWATER PUMPS
AERATOR
FLASH-MIX
GRANULAR ACTIVATED CARBON FILTERS (GAC)
RIVER DISCHARGE
TRANSFER PUMP
SLUDGE PUMPS
TO SANITARY LANDFIELD
CONTAMINATED WATER FROM SLUDGE DEWATERING
3 WELLS
CLARIFIER
RESERVOIR
2nd STAGE GAC
SLUDGE FILTRATION AND DRYNG SYSTEM
AERATOR AND FLASH-MIX
2 SAND FILTERS
1st STAGE GAC
SLUDGE STORAGE TANK

Figure 1. Ground water treatment facility.

Performance: The following observations were reported in the literature:

- Operation of the treatment system fails to achieve adequate removal levels for dichloroethane;
- Effluent concentrations of phenols, trichloroethane, and trichloroethylene meet treatment objectives; and
- Temporal variability is observed in raw ground water contaminant concentrations.

Limitations: The treatment system is probably sensitive to variations in influent loadings. Residual wastes generated in sludge and activated carbon must be disposed of.

Operating Problems: In the early stages of the treatment system operation, serious operating problems were caused by unexpected excessive biological growth within the whole treatment train, which resulted in the clogging of equipment (pumps, sand filter, granular activated carbon (GAC) contactors). The use of a combination of oxidizing agents (peroxide and chlorine) was found to be effective in limiting bacterial growth. However, although this problem has been partially solved, clogging of the GAC adsorbers by microbial growth still continues to be observed. The resulting effects on the performance and length of service of the adsorbers remain to be assessed and quantified.

Other operating problems encountered include losses of carbon during backwash, clogging of the packed media in the air stripping column, and control of the coagulation/sedimentation process (sludge settling, polymer efficiency). In addition to affecting treatment performance, these problems also increase operational costs.

Economics: Cost of the system was $2,950,000 (Canadian).

Status: Pumping and treatment system put into service July 1984.

Recommendations: No further action recommended.

References: NATO/CCMS Pilot Study: Demonstration of Remedial Action Technologies for Contaminated Land and Ground Water. 1st International Meeting, Washington, D.C. November 11-13 1987.

NATO/CCMS Pilot Study: Demonstration of Remedial Action Technologies for Contaminated Land and Ground Water. 1st International Workshop, Karlsruhe, Federal Republic of Germany. 16-20 March 1987.

INTERNATIONAL TECHNOLOGY FACT SHEET

Process: PCB Destruction Using a Diesel Engine

Type of Treatment: Thermal

Country: Canada

Institution/Contact: Chemical Waste Management Limited
Smithville, Ontario

Function: Destruction of PCBs.

Description: Chemical Waste Management Limited, assisted by Ontario Research Foundation and EPS, demonstrated the use of a diesel engine for the destruction of PCBs. The engine used a blend of diesel fuel and PCBs during the test burn, which was continually monitored for PCBs and by-products.

Performance: Test results suggest that it is an effective way of destroying PCBs.

INTERNATIONAL TECHNOLOGY FACT SHEET (continued)

Limitations: Only applicable to liquid PCBs.

Economics: None available.

Status: Feasibility report and test burns completed. Further development and testing of the system are being conducted in England through an agreement with the General Electric Company. Additional studies in Canada are also under consideration.

Recommendations: No further action recommended. The technology is limited to liquid organics and is currently experimental.

Reference: OECD - Lindsey, Alfred W. U.S. EPA Hazardous and Industrial Waste Division. Waste Management Policy Group - Trip Report. Summarizes the activities of the WMP Group at its 15th semi-annual meeting, 28-30 April 1982.

INTERNATIONAL TECHNOLOGY FACT SHEET

Title: Downflow Stationary Fixed-Film Reactors

Type of Treatment: Biological

Country: Canada

Institution/Contact: L. van den Berg
Division of Biological Sciences
National Research Council of Canada
Ottawa, Ontario, Canada K1A 0R6
Tel.: (613) 992-2087

Function: An anaerobic reactor for treating biodegradable toxic constituents.

Description: This is an anaerobic reactor with stationary films organized in vertical channels. The most successful reactors had fired clay or needle-punched polyester as film supports. Rigid, foamed PVC and glass reactors were ineffective.

Performance: In a test with an unspecified chemical industry waste, a COD of 14 g/L exhibited 81 percent conversion. The Canadian researchers say their reactor can withstand low temperatures, severe and repeated hydraulic overloadings, organic shockloads, sudden changes in waste composition, and starvation with little or no effect on subsequent performance. High rates of methane production can be obtained even while tailoring methane production to energy needs.

INTERNATIONAL TECHNOLOGY FACT SHEET (continued)

Limitations: A stationary film support is required to maintain the film of microorganisms in the reactor and to prevent settling of suspended solids on parts of the film support surface. Microorganisms do not adhere to all surfaces.

Economics: No data available.

Status: Commercial units are in use in Canada and Puerto Rico; agricultural and food processing wastes have been the main application.

Recommendations: Follow-up recommended when full-scale hazardous waste application is considered.

Reference: Technical Insights Inc. New Methods for Degrading/Detoxifying Chemical Wastes. Emerging Technologies No. 18. International Standard Book No. 0-914993-16-X, Library of Congress No. 85-51133. 1986.

INTERNATIONAL TECHNOLOGY FACT SHEET

Process: Aerobic Degradation of Contaminated Soil at Skrydstrup, Denmark

Type of Treatment: Biological

Country: Denmark

Institution/Contact: Danna Borg, M. Sc.
Ministry of Environment
National Agency of Environmental Protection
Strandgade 29, 1401 Copenhagen K, Denmark
Tel.: 45 157 8310

Function: Aerobic degradation of soil contaminated with trichloroethane, trichloroethylene, paints and paint sludges, and acids, selected as a NATO/CCMS Pilot Study in March 1987.

Description: Contaminated soil at this site is to be microbially degraded under aerobic conditions. The project is designed to treat the excavated soil onsite. A mound of 6,000 cubic meters of contaminated soil will be placed on a high density polyethylene membrane liner to control leachate. The layers of soil will be alternated with activated sludge from a wastewater treatment plant. The leachate is collected from the mound by a drainage system and recirculated throughout the mound using a system of pipes. The interior of the mound will be monitored for humidity and temperature. The aerobic treatment system will be operated for 3 months with sampling being performed 4 times/month. Processes may be modified and extended, based on sampling results. A diagram of the process is shown in Figure 1.

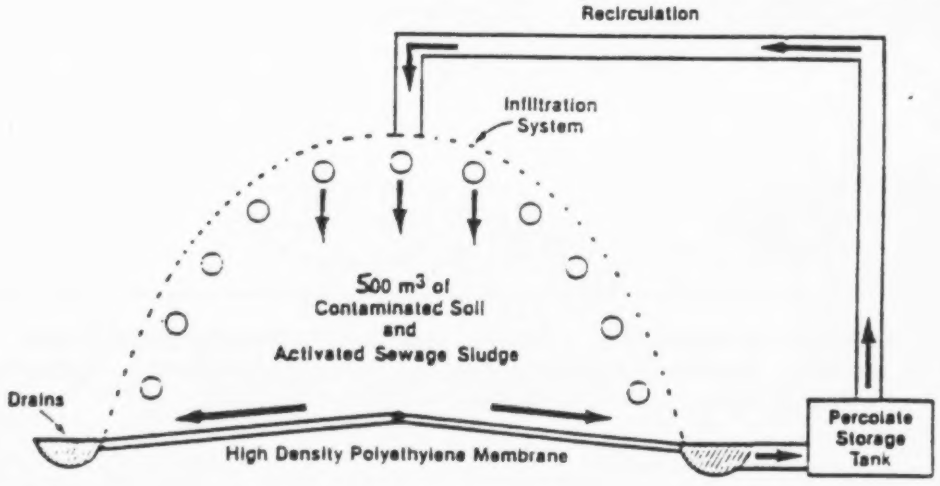

Recirculation
Infiltration System
500 m3 of Contaminated Soil and Activated Sewage Sludge
Drains
High Density Polyethylene Membrane
Percolate Storage Tank

Figure 1. Aerobic degradation of halogenated solvent contaminated soil.

Performance: During the research period (December 1986 - September 1987), samples were taken once a month in each of the two experiments. The results very slightly indicated that some biodegradation of chlorinated solvents had taken place. This may be partially explained by the unusually low temperatures. Biodegradation of haloalkyl phosphates has not been found. Since the original owners of the waste site burned much of their waste, soil samples will be taken to determine dioxin and furan content. If the soil is found to contain more dioxins and furans than background levels, the soil may have to be cleaned by supplementary measures (incineration), even if the content of the other contaminants is reduced by the biological treatment.

Limitations: Suitable only for aerobically degradable contaminants in excavated soil.

Economics: No economic data are available.

Status: An initial research period lasted from December 1986 - September 1987. The site and performance of the biodegradation continues to be monitored.

Recommendations: The results of this project should be monitored.

References: NATO/CCMS Pilot Study; Demonstration of Remedial Action Technologies for Contaminated Land and Ground Water. 1st International Meeting, Washington, D.C. November 11-13, 1987.

NATO/CCMS Pilot Study; Demonstration of Remedial Action Technologies for Contaminated Land and Ground Water. 1st International Workshop, Karlsruhe, Federal Republic of Germany. March 16-20, 1987.

INTERNATIONAL TECHNOLOGY FACT SHEET

Process: Anaerobic Degradation of Contaminated Soil at Skrydstrup, Denmark

Type of Treatment: Biological

Country: Denmark

Institution/Contact: Danna Borg, M. Sc.
Ministry of Environment
National Agency of Environmental Protection
Strandgade 29, 1401 Copenhagen K, Denmark
Tel.: 45 157 8310

Function: Anaerobic degradation of soil contaminated with trichloroethane, trichloroethylene, paints and paint sludges, and acids. Results of a NATO/CCMS Pilot Study in March 1987.

Description: This project, based on research conducted in the Netherlands, was designed to treat excavated soil onsite. A mound of 6,000 cubic meters of contaminated soil will be placed on a high density membrane liner to collect leachate. Layers of contaminated soil will be alternated with sludge from anaerobic digesters from a wastewater treatment facility. The mound will be covered with an impermeable membrane to limit oxygen transfer, thus creating a closed system. Leachate will be collected from this mound by a drainage system and recirculated throughout the mound using a system of pipes. Monitoring of the interior of the mound will measure humidity and temperature. The anaerobic treatment system will be operated for 3 months with sampling being conducted 4 times/month. Based on sampling results, the process may be modified and extended. A diagram of the process is shown in Figure 1.

Performance: Results of the project indicate that there has been little biodegradation of chlorinated solvents and no biodegradation of haloalkyl phosphates.

Limitations: Applicable only to soils that have been excavated and contaminants that can be anerobically degraded.

Economics: No economic data are available.

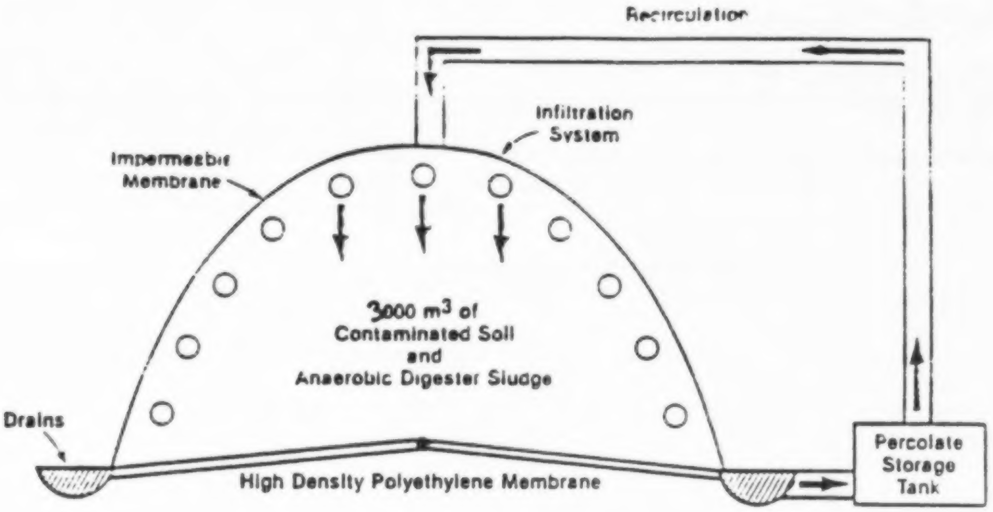

Recirculation
Infiltration System
Impermeable Membrane
3000 m^3 of Contaminated Soil and Anaerobic Digester Sludge
Drains
Percolate Storage Tank
High Density Polyethylene Membrane

Figure 1. Anaerobic degradation of halogenated solvent contaminated soil.

Status: An initial research period lasted from December 1986 - September 1987. The site and performance of the biodegradation continues to be monitored.

Recommendations: Results of this NATO/CCMS Pilot Study demonstration project should be monitored.

References: NATO/CCMS Pilot Study; Demonstration of Remedial Action Technologies for Contaminated Land and Ground Water. 1st International Meeting, Washington, D.C. November 11-13, 1987.

NATO/CCMS Pilot Study; Demonstration of Remedial Action Technologies for Contaminated Land and Ground Water. 1st International Workshop, Karlsruhe, Federal Republic of Germany, March 16-20, 1987.

INTERNATIONAL TECHNOLOGY FACT SHEET

Title: Aerobic Degradation in the Unsaturated Zone with Co-metabolism by Oxidation of Methane and/or Propane Gas

Type of Treatment: Biological

Country: Denmark

Institution/Contact: Karin Christiansen, Chemical Engineer
Ministry of the Environment, Denmark
National Agency of Environmental Protection
Strandgade 29
1401 Copenhagen K, Denmark

Function: Remediation of deep soil layers contaminated by chlorinated solvents.

Description: In the large-scale remediation of the Skrydstrup waste site, the waste was excavated; and the major part of the source of the contaminantion was thus removed. Chlorinated solvents which still remain in the soil layers under the site constitute a potential threat of ground water contamination.

Tests will demonstrate the effect on decomposition of chlorinated solvents using adapted bacteria instead of natural soil bacteria. The effects of using methane, propane and natural gas will be examined. In the field, a gas/air mixture will be injected through the unsaturated zone and water, possibly also nutrients and naturally adapted micro-organisms will be infiltrated. The gas/air mixture is injected via 7 injection wells with filters from approximately 0.5-1m below the ground water table. The gas is thus evenly distributed in the investigation area. A diagram of the treatment is shown in Figure 1.

Performance: Data on performance is not yet available due to the early status of the project.

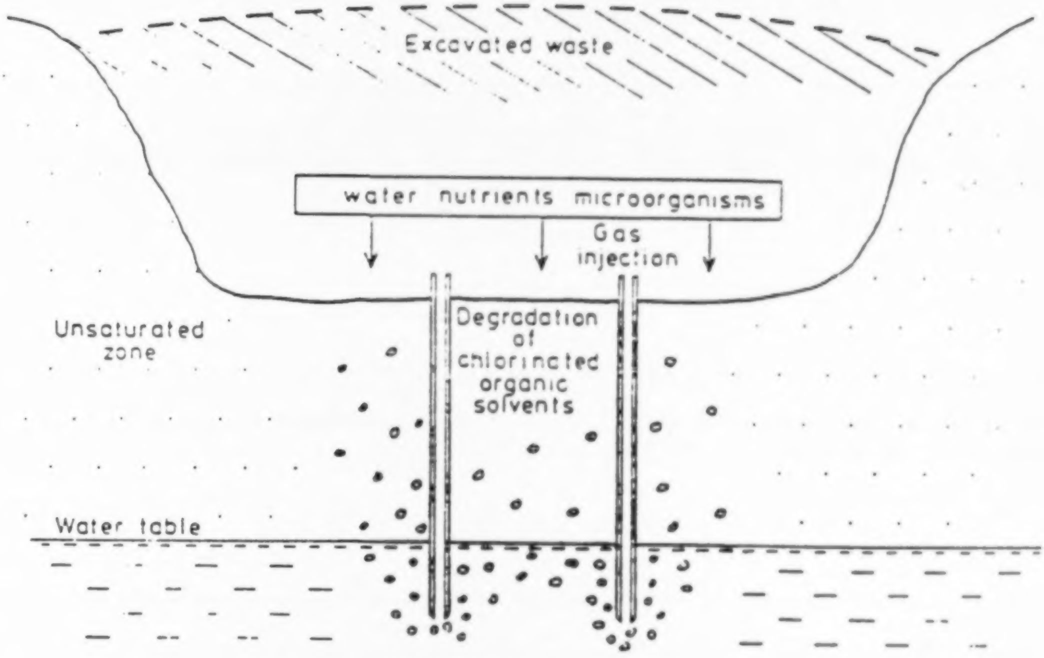

Excavated waste
water nutrients microorganisms
Gas injection
Degradation of chlorinated organic solvents
Unsaturated zone
Water table

Figure 1. Degradation of chlorinated organic compounds in the unsaturated zone by gas/air treatment.

INTERNATIONAL TECHNOLOGY FACT SHEET (continued)

Limitations: Limitations have not yet been established due to the early status of the project.

Economics: The planned budget totals 920,000 D.kr.

Status: The project consists of both laboratory tests and field tests. Together, the tests are expected to last almost 3 years, starting around the end of 1987.

Recommendations: Results of the NATO/CCMS Pilot-Study demonstration project should be monitored.

References: Christiansen, Karin "Skrydstrup Chemical Waste Disposal Site". Proceedings of the NATO/CCMS Pilot Study Demonstration of Remedial Action Technologies for Contaminated Land and Ground Water, 11-13 November 1987.

INTERNATIONAL TECHNOLOGY FACT SHEET

Title: Anaerobic Biodegradation in the Contaminated Zone by Addition of Sodium Acetate

Type of Treatment: Biological

Country: Denmark

Institution/Contact: Karin Christiansen
Ministry of the Environment, Denmark
National Agency of Environmental Protection
Strandgade 29
1401 Copenhagen K, Denmark

Function: In situ decomposition of chlorinated solvents in deep soil layers where aerobic conditions are difficult to create.

Description: The test set-up consists of 2 wells at 20 m distance from each other in the longitudinal direction of the plume, and 4 observation wells. Sodium acetate will be added to one of the 2 wells and the chlorinated organic compounds will decompose by means of methanogene bacteria. Methanogene bacteria, which are believed to promote reductive dichlorination, are strictly anaerobic and use organic matter or CO_2 as electron acceptors. During reinfiltration in the upstream well, sodium acetate is added, up to 1.5-10 mmol/l. A diagram of the planned test set-up is shown in Figure 1.

Performance: Data not yet available.

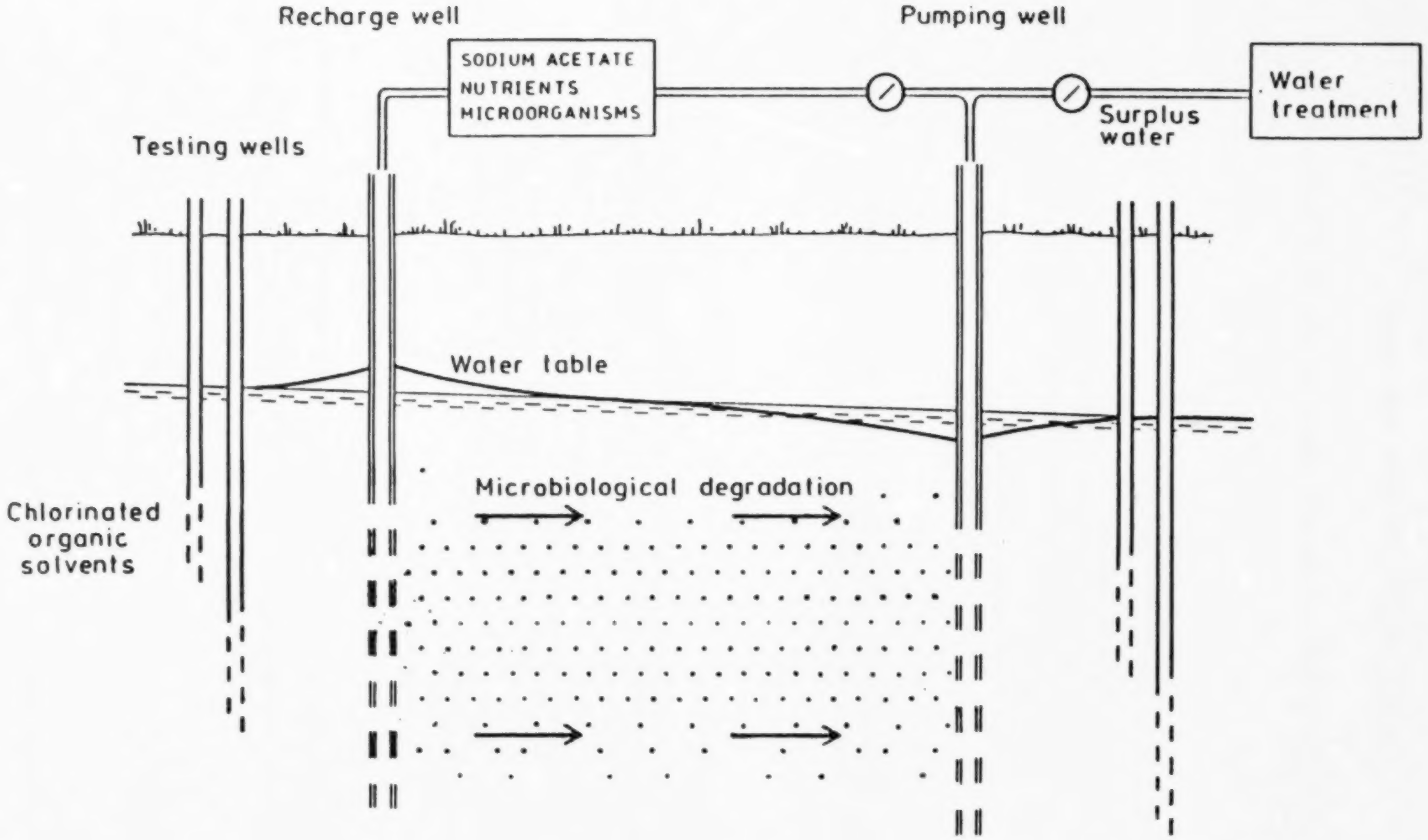

Recharge well
Pumping well
SODIUM ACETATE
NUTRIENTS
MICROORGANISMS
Water treatment
Surplus water
Testing wells
Water table
Microbiological degradation
Chlorinated organic solvents

Figure 1. Anaerobic microbiological degradation in the ground water zone. Planned test set-up.

Limitations: Data not yet available.

Economics: The test budget totals 1,200,000 D.kr.

Status: The test period is 2 years, to begin some time in early 1988.

Recommendations: Monitor results of the NATO/CCMS Pilot Study.

References: Christiansen, Karin "Skrydstrup Chemical Waste Disposal Site". Proceedings of the NATO/CCMS Pilot Study Demonstration of Remedial Action Technologies for Contaminated Land and Ground Water, 11-13 November 1987.

INTERNATIONAL TECHNOLOGY FACT SHEET

Process: Ground Water Treatment by Aeration and Nutrient Addition

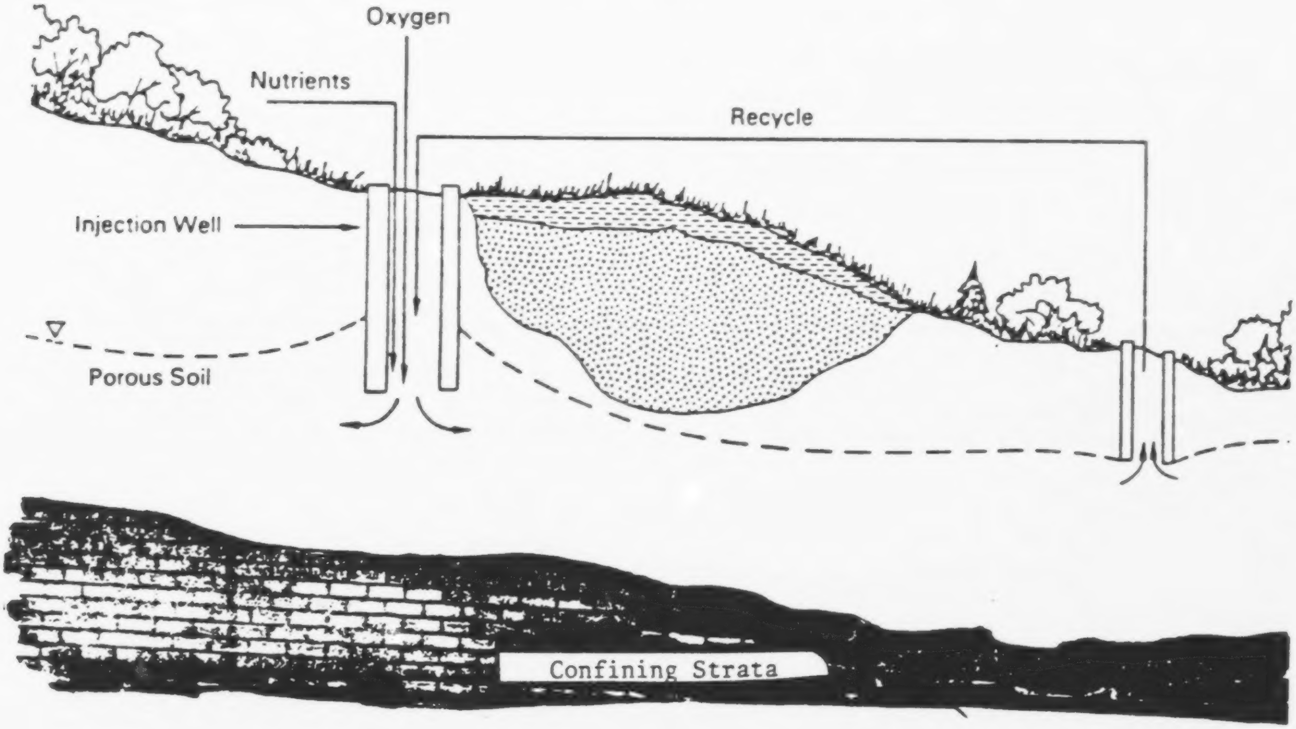
Type of Treatment: Biological

Country: Federal Republic of Germany

Institution/Contact: K.A. Childs, Senior Advisor
Landfill Site Remediation
Waste Management Branch
Environmental Protection Service
Environment Canada
Ottawa, Ontario K1A 1C8 Canada
Tel.: (819) 997-2800

Function: In situ treatment of ground water.

Description: Ground water from an aquifer contaminated by hydrocarbons was extracted and treated by aeration and nutrient addition (nitrate and phosphate) followed by re-injection. Degradation of hydrocarbons was accelerated by increasing the temperature of the re-injected water. A diagram of this process is shown below.



Performance: Most effective in treating hydrocarbons and other organics.

Limitations: Disadvantages include the selectivity of the culture and the fact that nutrients used to stimulate reactions may have adverse effects on water quality. Maintaining the reactions may be a problem, and the long-term effectiveness is not yet known.

Economics: No data available.

Status: Not known.

Recommendations: Update status.

Reference: NATO/CCMS - Childs, K.A. Environment Canada. Pilot Study on Contaminated Land - Project D: Liquid Phase Management of Contaminated Land Including Horizontal and Vertical Barriers, Treatment and Modeling. December 1983.

INTERNATIONAL TECHNOLOGY FACT SHEET

Process: Encapsulation/Stabilization Techniques Using Thermoplasts and Resins

Type of Treatment: Physical/Chemical

Country: Federal Republic of Germany

Institution/Contact: Hans L. Jessberger/Ruhr-Universität Bochum

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Function: Encapsulation of soils.

Description: Thermoplasts and resins are mentioned in European literature as admixtures to stabilize and solidify contaminated material. Formed (and solidified) contaminated masses can be encapsulated, e.g., with HDPE membranes.

The references given regarding thermoplasts, resins, and HDPE are:

1. Wiedemann HU: Verfahren zur Verfestigung von Sonderabfällen und Stabilisierung von verunreinigten Böden: Stand der Erkenntnisse und Anwendungsmöglichkeiten. Berichte des Umweltbundesamtes 1/82, ISBN 3-503-02157-4, Berlin, 1982.

2. Wackernagel K: Deponieverhalten von Verfestigungsprodukten mineralöl-haltiger Schlämme. Zweckverband Sondermüllplätze Mittelfranken, Schwaback, im Auftrage des Umweltbundesamtes, Berlin, 1980.

3. HDPE = High Density Polyethylene. Tongers H: Geolock - Eine neue Möglichkeit für die Abschirmung grundwassergefährdender Deponien. Baugrundtagung, Düsseldorf, 1984.

Performance: Not available.

Limitations: There can be an unfavorable reaction between the contaminated material and the additives. Because of possible porosity, the contaminants can be leached out.

Economics: Costs reported for stabilization/encapsulation in general: 50 to 1000 DM/ton.

Status: Various stages of development.

Recommendations: Update status of leachability studies using thermoplasts and resins.

Reference: TNO-Assink, J.W., and W.J. van Den Brink. 1st International TNO/BMFT Conference on Contaminated Soil, November 11-15, 1986. Utrecht, The Netherlands. Martinus Nijoff Publishers, Boston, MA. 1986.

INTERNATIONAL TECHNOLOGY FACT SHEET

Process: Low Alkaline, Waterglass Grouting - DYNAGROUT^{R}

Type of Treatment: Barrier

Country: Federal Republic of Germany

Institution/Contact: Author: Dr. H.J. Hass
Company: Dynamit Nobel (developed the gel)

Function: Stable grouting gels for bottom seals and sealing walls.

Description: The grouting material used is a low-alkaline waterglass-type with a high SiO_2/Na_2O ratio, called DYNAGROUT PPN. The developer reports the resistance to harmful substances, density, low syneresis, strength, and the practicable gel times of the silicate gels are achieved by the DYNAGROUT PPN two-component hardener system.

Sealing walls resistant to aggressive matter have been developed to be usable in the two-phase and single-phase process. An optimally harmonized material with a suitable grain distribution and high resistance to noxious substances has been selected to achieve this aim. The remaining porous voids are filled with DYNAGROUT PPN gel. Silicate gels for bottom liners using special gelification agents have been fully tested and injection gels are ready for use. The well-known and conventional techniques of slurry trench construction, soil consolidation and sealing by means of grouting may be used for the execution of the construction work using the described new materials.

The project that tested the viability of this barrier technology received a Federal research grant of $0.7 million, met by an equivalent industry contribution for a total grant of $1.5 million.

Performance: The following table shows a small selection of the results achieved.

Test substances	Permeability after 180 days (k-value)	Permeability after 360 days (k-value)
Chlorinated hydrocarbons (CHC)	5.6×10^{-12} m/s	Nearly impermeable
Organic acids	8.3×10^{-10} m/s	1.2×10^{-9} m/s
Organic bases	2.6×10^{-10} m/s	5.0×10^{-10} m/s
Water	2.9×10^{-10} m/s	3.9×10^{-10} m/s

Limitations: None mentioned.

Economics: No data available.

Status: DYNAGROUT PPN silicate gels have been tested against potentially harmful substances and their mixtures for approximately 1 year. Development of the commercial production phase is ready to begin.

Recommendations: Update status and applicability.

Reference: Brown, Margaret. Correspondence of October 1987.

TNO-Assink, J.W., and W.J. van Den Brink. 1st International TNO/BMFT Conference on Contaminated Soil, November 11-15, 1986. Utrecht, The Netherlands. Martinus Nijoff Publishers, Boston, MA. 1986.

INTERNATIONAL TECHNOLOGY FACT SHEET

Process: Mechanical Separation of Contaminated Dredged Material

Type of Treatment: Physical

Country: Federal Republic of Germany

Institution/Contact: J. Werther, R. Hilligardt, H. Kroning
Technical University Hamburg - Harburg

Function: This process separates fine particles contaminated by heavy metals from coarse particles in dredged material.

Description: In processing harbor sludge, it was found that 80 to 90 percent of the heavy metals are fixed to fine clay particles in the size fraction between 0 to 25 microns. The fraction of clay with particle sizes less than 25 microns occupied 30 percent of the total sludge material. A plant was developed to separate the fines from the coarse fraction. Since only a fraction of the original volume of sludge remains to be treated, costs are reduced.

A pilot plant was developed, consisting of a rough and an efficient classifier, a hydrocyclone and an elutriator. These units were used in succession to separate the coarse from the fines. The liquid fluidized bed formed in the bottom section of the elutriator provided a means of cleaning the coarse fraction from the adhering fines.

A further purpose of this pilot plant was to test novel methods for the dewatering of the classified sludge. Decanting centrifuges, as well as filter presses are being investigated in order to find financially acceptable alternatives.

Performance: Figure 1 demonstrates that the clean sand separated from the sludge has a heavy metal content on the order of magnitude found in naturally occurring sandstones. First pilot plant results largely confirm laboratory data, thus indicating the basic feasibility of the classification concept.

INTERNATIONAL TECHNOLOGY FACT SHEET (continued)

Limitations: Not available.

Economics: No data available.

Status: Laboratory results were promising, so a pilot plant was built by Hamburg's Amt fur Strom und Hafenbau. The flow diagram of this plant is shown in Figure 2. The pilot plant, with a capacity of 1,000 m^3/hr, has been in operation since May 1985.

Recommendations: Additional information should be sought to determine, for example, how this method compares in terms of economics and practical limitations to simpler classification methods such as sieving.

Reference: Bruce, A.M. et al. New Developments in Processing of Sludges and Slurries. Commission of The European Communities. Elgevier Applied Science Publishers, New York. 1986.

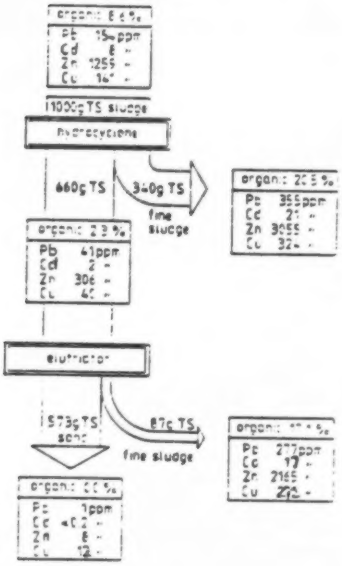

organic
Pb ppm
Cd
Zn 1255
Cu
1000g TS sludge
hydrocyclone
660g TS
340g TS
fine sludge
organic
Pb 355ppm
Cd
Zn 3055
Cu 324
organic
Pb 41ppm
Cd 2
Zn 306
Cu
elutriator
573g TS
sand
87g TS
fine sludge
organic
Pb 277ppm
Cd 17
Zn 2165
Cu
organic
Pb 1ppm
Cd
Zn 8
Cu 12

Figure 1. Mass balance and distribution of heavy metals (percentage organic material determined by oxidation at 600°C; TS = dry material).

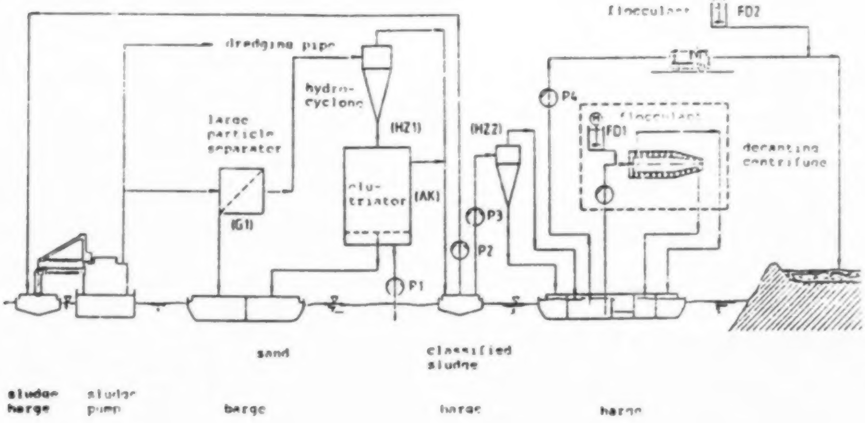

flocculant
FD2
dredging pipe
hydro-cyclone
large particle separator
(HZ1)
(HZ2)
P4
flocculant
FD1
decanting centrifuge
elu-triator
(AK)
(G1)
P3
P2
P1
sand
classified sludge
sludge barge
sludge pump
barge
barge
barge

Figure 2. Pilot plant for the mechanical processing of dredged sludges.

INTERNATIONAL TECHNOLOGY FACT SHEET

Process: Continuous High-Pressure (CHP) Filter Press

Type of Treatment: Physical

Country: Federal Republic of Germany

Institution/Contact: U. Loll/Abwasser-Abfall-Aquaztechnik
D-6100 Darmstadt, Federal Republic of Germany

Function: Dewatering of sludges.

Description: The CHP-filter press is a continuously working, high-pressure press for solid/liquid separation of sludge-like suspensions. Developmental design criteria included the following features:

- Continuous sludge feeding;
- Continuous increase of pressure;
- Continuous cake outlet;
- Continuous filter cloth washing;
- Highest possible regulation of the flow rate;
- Good dewatering results;
- High separation cut;
- Low amount of machinery (small dimensions);
- Low energy demand;
- Highest possible pressure up to 20 kp/cm^2; and
- Pressure control in amount and activity time.

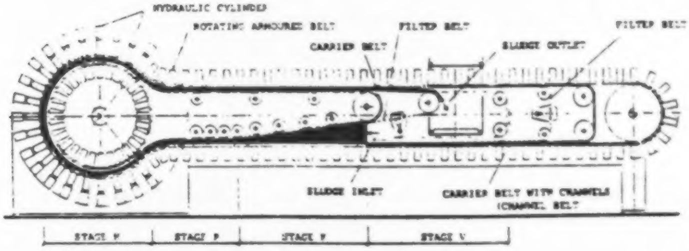

HYDRAULIC CYLINDER
ROTATING ARMOURED BELT
FILTER BELT
CARRIER BELT
SLUDGE OUTLET
FILTER BELT
SLUDGE INLET
CARRIER BELT WITH CHANNELS
(CHANNEL BELT
STAGE IV
STAGE III
STAGE II
STAGE I

Figure 1. Elements of the continuous high pressure filter press.

Performance: Reportedly better than the other methods: centrifuge, belt filter press, vacuum filters, etc.

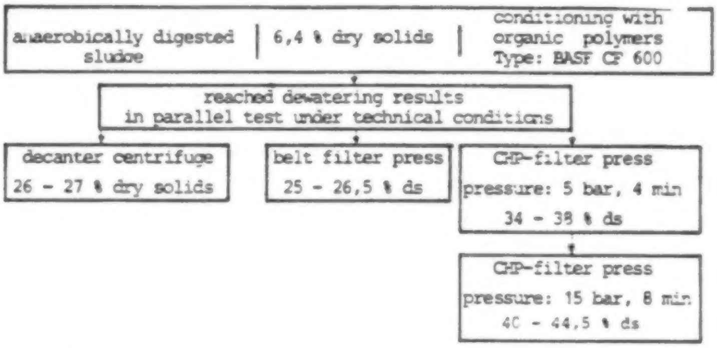

anaerobically digested sludge
6,4 % dry solids
conditioning with organic polymers Type: BASF CF 600
reached dewatering results in parallel test under technical conditions
decanter centrifuge
26 - 27 % dry solids
belt filter press
25 - 26,5 % ds
CHP-filter press
pressure: 5 bar, 4 min
34 - 38 % ds
CHP-filter press
pressure: 15 bar, 8 min
40 - 44,5 % ds

Figure 2. Results of a parallel test with three different dewatering machines with special reference to the CHP high-pressure filter press.

Limitations: None available.

Economics: Reportedly less expensive than the other dewatering techniques. Considering manpower, capital and energy costs, the total cost is about the same as the other methods, but the results are better.

Status: There are two plants in operation in West Germany. Licenses for the technology are being considered in Japan and the U.S. Production model was made available in the Autumn of 1986.

Recommendations: Monitor progress.

Reference: Bruce, A.M. et al. New Developments in Processing of Sludges and Slurries. Commission of The European Communities. Elgevier Applied Science Publishers, New York. 1986.

INTERNATIONAL TECHNOLOGY FACT SHEET

Process: In Situ Aerobic Biodegradation of Aromatic Hydrocarbons

Type of Treatment: Biological

Country: Federal Republic of Germany

Institution/Contact: Dr.-Ing. Peter Geldner
Associate Consultant Engineer
Kaiserallee 61,
Postfach 1627
D-7500 Karlsruhe 1, Federal Republic of Germany

Function: In situ remediation of benzene and other aromatics by stimulating biological degradation with nitrate and nutrient-enriched injection water.

Description: A biodegredation technique was applied to a site in the Upper Rhine Graben of the FRG, contaminated by benzene and other aromatics. An artificial ground water flow circuit was established and controlled by injection and extraction wells. Degredation by naturally occurring microorganisms was stimulated by heating the water and by adding nitrate and essential nutrients such as phosphate and ammonia to the injected water. A pure water circuit of drinking water standards was maintained to prevent contaminated flusing water from entering the surrounding aquifer.

Figure 1 shows the flushing and pure water injection circuits for this process. The pure water is strip-aerated and filtered to separate iron and manganese and also methane from the system. This is done prior to injection to prevent clogging of the injector wells. A similar arrangement is used to strip the extracted water of hydrocarbons in the flushing circuit. The pure water injection system consisted of eight wells, 9 meters deep. The flushing circuit had four wells of the same kind. Nine extraction wells were located on the opposite side of the area of contamination from the injection wells. Pure water could be injected at a rate of up to 20 L/sec with an average of 10 L/sec. The flushing/injection rate was 5 L/sec, and the extracted water was adjusted to be always above this rate.

Performance: The remedial action described has been accepted as successful by the responsible environmental authorities. Degradation data from one of the extraction wells is shown in Table 1.

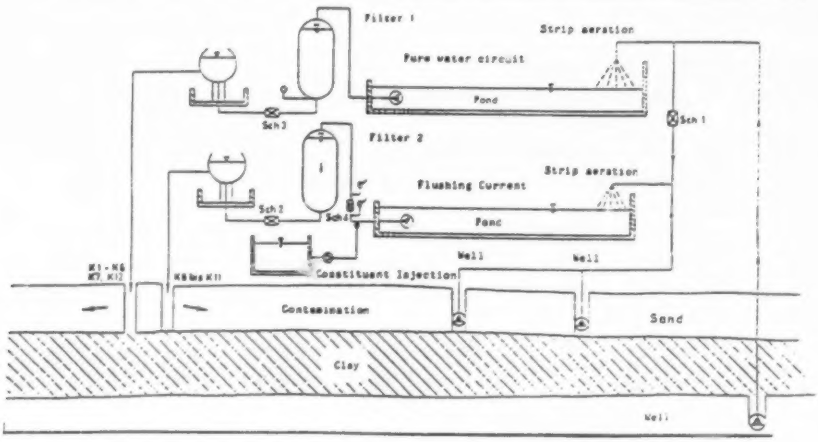

Filter 1
Strip aeration
Pure water circuit
Pond
Sch 3
Sch 1
Filter 2
Strip aeration
Flushing Current
Sch 2
Sch 4
Pond
Well
Well
Constituent Injection
K1 - K6
K7, K12
K8 bis K11
Contamination
Sand
Clay
Well

Figure 1. Scheme of the remedial facilities.

TABLE 1. DECAY OF HYDROCARBON CONCENTRATIONS IN EXTRACTION WELL NO. E7

	Concentration (mg/L)					
	Period (months)					
	1	3	5	7	9	11
Xylene	5.5	4.5	3.1	2.0	1.1	0.8
Toluene	2.8	1.6	0.8	0.2	n.d.	
Benzene	1.3	0.9	0.1	n.d.		

Limitations: The process has numerous limitations based on its in situ and site-specific nature. Most limitations concern the soil and ground conditions.

Economics: Implementation of in situ biodegradation techniques is not yet a standardized engineering method. Therefore, more developmental work has to be done on this project, so that an economic classification in terms of costs/meter^3 of remediated soil can be given.

Status: Engineering modifications or alternatives may be needed for different applications.

Recommendations: Monitor results with Dr. Geldner. Possibly conduct more detailed study of Dr. Geldner's approach.

Reference: U.S. EPA. HWERL Proceedings: 2nd International Conference on New Frontiers for Hazardous Waste Management. Pittsburgh, PA. September 27-30, 1987.

INTERNATIONAL TECHNOLOGY FACT SHEET

Process: Solidification and Stabilization of Acid Resin in Soils by the Addition of Lime

Type of Treatment: Physical/Chemical

Country: Federal Republic of Germany

Institution/Contact: Dr. Hartmut U. Wiedemann
Umweltbundesamt
Bismarkplatz 1
1000 Berlin 33
Federal Republic of Germany

Function: Solidification and stabilization of hazardous wastes in soils and sludges.

Description: Acid resin can be stabilized by the addition of lime. The lime causes polymerization of the tar constituents of acid resins. No special additive is necessary; calcium carbonate, calcium oxide, calcium hydroxide, and alkaline slags and ashes are all effective. Temperatures of 150 to 200°C can be reached in the reaction of acid resin with lime, which leads to partial coking of organic constituents.

Performance: Not specified.

INTERNATIONAL TECHNOLOGY FACT SHEET (continued)

Limitations: Acid resin wastes only.

Economics: No information available.

Status: Unknown.

Recommendations: For the practical adaptation of the appropriate processes, it is essential to control the reaction temperature, steam emission, other emissions (SO_2, hydrocarbons), corrosion problems, and abrasion problems in the plant used. No further action is recommended.

Reference: Wiedemann, Dr. Hartmut U. Umweltbundesamt. Process for Solidifying Special Wastes and Stabilizing Contaminated Soils - State-of-the-Art and Possible Applications. January 1982.

INTERNATIONAL TECHNOLOGY FACT SHEET

Process: Engineered Salt Cavern Ultimate Disposal

Type of Treatment: Disposal

Country: Federal Republic of Germany

Institution/Contact: Dr.-Ing. Hans J. Schneider
Kavernen Bau - Und Betriebs-GmbH
Roscherstrasse 7, D-3000 Hannover 1
Federal Republic of Germany
Tel.: 0-11-34-846-49

Function: Permanent disposal of hazardous wastes in salt caverns.

Description: Salt caverns are constructed in salt formations by solution mining. Access wells are installed with standardized deep drilling techniques, down to the projected final cavern depth. The last cemented casing typically extends 100 to 200 m into the salt formation. Three concentric rings are installed for the actual solution mining process. Freshwater or seawater is pumped into the cavern zone through the inner ring. The water dissolves the salt on the walls of the cavern and the brine is extracted through the first annulus. The outer annulus is used for blanket material (i.e., oil) injection to control vertical leaching in the roof zone.

Before waste is deposited, the brine-filled cavern is evacuated by use of submersible pumps. The waste is fed into the cavern via the access well. It will be continuously delivered at a projected annual rate of 100,000 to 200,000 m^3 down an additional string hung in the well. This ring protects the outer casing against corrosion and abrasion and can be pulled out and/or replaced in event of damage. After complete filling of the cavern with waste, the cavern must be permanently sealed against the biosphere. For this purpose the open borehole above the cavern roof is filled with salt to establish a natural salt barrier while the cased hole is filled with cement, clay, and bitumen. The surface site is recultivated and returned to its original use.

Performance: The construction of solution-mined salt caverns is a technique that has been an accepted method of disposal for the past two decades. More than 1,000 salt caverns are currently in use worldwide, storing primarily crude oil, oil products, and natural gas.

Salt makes an excellent material as a geologic repository because it exhibits plastic flow. This property allows the salt to conform to changes in pressure or movement, inhibiting cracking of the dome. Also, it is assumed that since the salt domes have existed for millions of years, their environment is not threatening in any way, and they will continue to be extremely stable for millions of years to come.

Limitations: The construction places certain requirements on the geological characteristics of the salt structure, such as sufficient thickness, extension above depths of 2,000 m, and relatively pure salt composition. In addition, the solution-mining technique itself has specific requirements such as a water supply of 200 to 400 m^3/hr and brine disposal.

Economics: Projects to date have average construction costs of between DM 60 and DM 100/m^3 in Germany, and between US $20 and $80/$m^3$ in the USA. There are no cost estimates available yet concerning waste conditioning and operating costs.

Status: In Germany, in the State of Lower Saxony, plans for the siting and permitting of a solution-mined salt cavern for final disposal of hazardous wastes is underway. Planning and construction will last from 1980-1992, with commencement of operation to begin in 1993. A salt repository for hazardous wastes will be built by Textor of Houston in eastern Texas after permitting in 1988. They expect to be operational by 1991. This company solution-mines and seals their caverns in the same way, but solidifies and pellitizes their wastes prior to deposition underground.

Recommendations: Check status and methods of stabilization and solidification in the German salt caverns.

References: Schneider, Dr. H.J., Crotogino, A., of Kavernen Bau-und Betriebs-GmbH. Mail correspondence to J. Hyman of Alliance Technologies. January 8, 1988.

Stone, R.B., Covell, K.A., and L.W. Weyand. Using Mined Space for Long-Term Retention of Nonradioactive Hazardous Waste Volume 2 - Solution Mined Salt Caverns. Contract No. 68-03-3191 for the Land Pollution Control Division, HWERL, EPA. December 1984.

Texstor. Brochure on facility in Texas for permanent containment of hazardous waste, deep underground in a salt dome. 1988.

U.S. EPA. HWERL Proceedings: 2nd International Conference on New Frontiers for Hazardous Waste Management. Pittsburgh, PA. September 27-30, 1987.

INTERNATIONAL TECHNOLOGY FACT SHEET

Process: Salt Mine Disposal and Storage - Herfa-Neurode Facility

Type of Treatment: Disposal

Country: Federal Republic of Germany

Institution/Contact: Dr. Gunnar Johnsson, Managing Director
Kali und Salz AG
Friederick-Ebert Str. 160
D3500 Kassel, P.O. Box 102029
Federal Republic of Germany
Tel.: (0561) 301-395

Function: Disposal and storage of hazardous wastes in an abandoned mine in a geologically stable salt formation.

Description: In 1972, Kali und Salz established Untertage-Deponie (UTD) to operate an underground waste disposal facility in the mined-out section of the Kaliwerk Wintershall potash mine, which is located at Herfa-Neurode in the State of Hessen. This section of the mine was shut down in 1970. Active mining of potash continues 12 km east to west and 10 km north to south of the waste disposal facility.

This area is geologically unique, located in a stable salt formation formed 250 million years ago. The salt deposit is between 200 and 300 metres thick and is at a depth of about 700 to 800 metres. Overburden includes impermeable clay and shale layers and the salt deposit is virtually impervious to water. Storage in the caves is manifested so that special waste can be excavated later on for recycling, although 90 to 95 percent of the waste is probably permanently stored.

Performance: Not specified.

Limitations: Wastes not accepted at this facility include: all liquids; wastes which might develop the characteristics of explosiveness, ignitability or toxicity in the prevailing underground gas-air mixture; wastes with a high vapor pressure; wastes which might have a tendency to self-ignition or instability; wastes which might react with the surrounding salt; or radioactive wastes. Wastes rendered to a semi-solid consistency are acceptable. In the event of drum puncture, no free flowing liquids should escape and contaminate the surroundings. While the UTD operation at Herfa-Neurode is an example of waste disposal for wastes which cannot be treated by existing technology, the relatively low cost of waste disposal at this facility probably attracts some wastes which could be treated elsewhere.

Economics: The cost of waste disposal at this facility is $85.00/ton (Canadian).

Status: In 1981, 47,000 tonnes of waste were deposited at the facility, although the facility usually averages about 35,000 to 40,000 tonnes/year of which about 25 percent originates from foreign countries. Approximately 100,000 cubic meters of storage space/year is required. The facility is presently licensed for 15 years, although some 50 years of capacity presently exist. An additional 30 years potential capacity is created annually from ongoing potash mining operations.

Recommendations: Update status including the stability of old mines.

Reference: Gulevich, Wladimir. Hazardous Waste Management Programs in Germany, Austria, and Switzerland. A Report to the German Marshall Fund of the United States. May 1984.

Proctor & Redfern Group, Toronto Ontario. Ontario's Waste Management Corp. European Tour. April 26 to May 7, 1982.

INTERNATIONAL TECHNOLOGY FACT SHEET

Process: In Situ Oxidation of Arsenic in Ground Water Using Potassium Permanganate ($KMnO_4$)

Type of Treatment: Chemical

Country: Federal Republic of Germany

Institution/Contact: Dipl.-Ing. Klaus Stief, Water Management Division
Federal Environmental Agency
Umweltbundesamt, Bismarckplatz 1
D-1000 Berlin 33, Federal Republic of Germany
Tel.: 030-8903-1 or Ext. 253

Prof. Dr. Georg Matthess
Institute of Geology and Paleontology
University Kiel
2300 Kiel,
Olshausenstrasse 40/60
Tel.: 0431/880 2858

Function: Accelerated oxidation of trivalent arsenic into pentavalent arsenic and precipitation of complex arsenic-iron-manganese compounds.

Description: The process consists of injecting a solution of $KMnO_4$ and water into the ground through injection wells and piezometers. The solution naturally mixes with contaminated ground water and the natural oxidation process of the arsenic is accelerated. The source of the arsenic was the residue from a zinc ore smelter located near Cologne, Federal Republic of Germany.

Performance: The arsenic concentrations were initially reduced in average from 13.6 mg/L to 0.06 mg/L after 2 years. A total of 29 metric tons of $KMnO_4$ was injected. A later increase to 0.4 mg/L indicated that the mixing of contaminated water and oxidizing solution was not complete. Injections were repeated twice in later years.

Limitations: Mixing of contaminated water and the oxidizing solution was not complete, as noted above.

Economics: Total costs amounted to about DM 750,000 for monitoring and injection wells, injection of $KMnO_4$, and disposal of arsenic-containing sludges as hazardous waste.

Status: The operation took place from December 1976 to May 1977. No update available at this time.

Recommendations: Check on status. Possibly investigate.

Reference: Matthess, G. "In-Situ Treatment of Arsenic-Contaminated Ground Water." The Science of the Total Environment. Vol. 21, pp. 99-104. 1981.

Matthess, G., Moser, H., and P. Trimborn. Single Well Measurements as a Tool for Decontamination of an Arsenic-Contaminated Ground Water Plume. IAHS Publication No. 146. pp. 259-265. 1983.

NATO/CCMS - Smith, M.A. Building Research Establishment, Department of the Environment, England. Draft Report of the NATO/CCMS Study Group on Contaminated Land. February 20, 1984.

INTERNATIONAL TECHNOLOGY FACT SHEET

Process: In Situ Anaerobic Biodegradation of Hydrocarbons in the Subsurface

Type of Treatment: Biological

Country: Federal Republic of Germany

Institution/Contact: Dr.-Ing. Gerhard Battenmann
c/o Ingenieurburo Dr. Ing. G. Bjornsen
Beratende Ingeniersgesellschaft
Kurfurstenstrasse
5400 Koblenz, Federal Republic of Germany
Tel.: (0261) 39006-62

Function: Subsurface hydrocarbons are removed from the upper aquifer. This prevents ground water transport of the hydrocarbons to a useable deeper aquifer that is recharged by the upper aquifer. The use of a barrier would be ineffective as hydrocarbons would not be removed from subsurface and impermeability of barrier could not be ensured.

Description: A study of in situ biodegradation of hydrocarbons in the subsurface was carried out at the Rhine Valley experimental site. Biodegredation of immobile hydrocarbons from the subsurface required flushing of the contaminated volume. Bacteriological investigations initially indicated the presence of the needed bacteria in subsurfaces. All water for infiltration was saturated with oxygen and enriched with nitrates which serve as oxygen donators in the anaerobic biodegradation of hydrocarbons to water and carbon dioxide. The flushing water removed metabolic waste products of bacteria which may have inhibited growth. The complete oxidation of 1 g of hydrocarbons to H_2O and CO_2 requires 4 g of nitrates. Ground water modelling was required to determine location of both injection and removal wells for flushing water so as to ensure saturation of the contaminated area while also minimizing excess releases of nitrates to clean areas. Effectiveness of program was determined by effectively monitoring ground water levels, discharge and removal rates of flushing wells, nitrate content and concentration of hydrocarbons, aromatics and alphiatics in subsurface.

Performance: At an injection rate of 5 L/second with an input concentration of 300 mg/L of nitrate, approximately 130 kg of nitrates/day were introduced into the upper aquifer of the Rhine Valley experimental site. In the 120 days of the experiment, about 7.5 tons of hydrocarbons were removed from the subsurface (approximately 1/3 of the total HC content).

Limitations: The use of biodegradation is impractical in the absence of bacteria needed for the decomposition of hydrocarbons or in the presence of inhibitors of bacterial growth such as lead from fuel. Investigations required to determine applicability include: bacterial, chemical, ground water modelling, followed by extensive monitoring during operation. Steps must be taken, including the installation of protective well systems, to prevent contamination of clean areas with excess nitrates.

Economics: No information provided.

Status: Large-scale/experimental.

Recommendations: Further study is needed to better characterize this technology.

Reference: Battermann, Gerhard. A Large-Scale Experiment of In Situ Biodegradation of Hydrocarbons in the Subsurface. Presented at the Symposium on Ground Water in Water Resource Planning. Federal Republic of Germany. 1983.

INTERNATIONAL TECHNOLOGY FACT SHEET

Process: Mobile Rotary Kiln Treatment of Contaminated Soil at Unna-Boenen

Type of Treatment: Thermal

Country: Federal Republic of Germany

Institution/Contact:	Mr. Kowollik RAG/Bergbau AG Niederrhein Silberstrasse 22 D-4600 Dortmund 1, FRG Tel.: 0201-177-2237	Joachim Ronge, General Mgr. Ruhrkohle Aktiengesellschaft Rellinghauser Strasse 1 Postfach 10 32 62 D-4300 Essen 1, FRG Tel.: 0201-177-1

Function: Thermal treatment of contaminated soil in a rotary kiln at a former coke oven plant. This project was selected as a NATO/CCMS Pilot Study (March 1987).

Description: The site at Unna-Boenen in Northrhine-Westphalia is a former coke oven plant of 250,000 square meters in area contaminated with aromatic hydrocarbons, tars, and acid resins. In the thermal treatment system, the contractor, Ruhrkohle Aktiengesellschaft, has decided to use both a direct and indirect heating process. A pilot test study was conducted and results have been encouraging. A full-scale test plant is designed for a throughput of 7 ton/hour at a moisture content of up to 20 percent by weight, and volatile matter of 5 percent by weight. The 50 ton/hour full-scale demonstration plant is expected to be operational by the Fall of 1987. The plant will be constructed as a transportable unit allowing it to be used at other sites.

The concept includes the following process steps. The soil is crushed by mechanical means before entering two rotary kilns. The soil is heated to temperatures of 600°C, releasing the volatile contaminants. On leaving the rotary kiln, the soil is cooled by water, after which it is prepared for return to the site. The off gases are heated to post combustion at temperatures of up to 1,300°C. The air is then scrubbed prior to being released. Energy requirements are reduced since the high-temperature phase does not include soil volume. Also, there is comparably less gas to clean (more stochiometric incineration of gases).

INTERNATIONAL TECHNOLOGY FACT SHEET (continued)

Description (cont.): Ruhrkohle is planning an additional thermal process. This new plant will be used for direct heating of the rotary kiln. The extent of contamination in the soil usually amounts to 1 percent by weight of the soil. The plant has been designed for this concentration. Applying temperatures of between 450° and 600°C, an average throughput of 35 to 50 ton/hour is attained. This throughput is dependent on soil moisture, contaminant concentration, and applied temperature. The cold soil is passed through the drum under rotating action. The soil is heated indirectly by heat exchange with the drum, as well as by a countercurrent flow of hot gases. Further heating of the soil to the required temperature occurs in the subsequent drum. In this drum, the soil is heated by radiant heat from the flame of an oil burner, as well as by exposure to the hot combustion gases. On leaving the rotary kiln, the soil is cooled by water and prepared for return to the site. The waste gas leaving the drum passes through a cyclone separator. The gases are then recycled to the rotary kiln drum. The waste gases are heated and sent to a combustion chamber where the remaining volatiles are burned at 950°C. The temperature may ultimately be boosted to 1,200°C to assure complete destruction. The waste gases are scrubbed prior to release.

Performance: The destruction efficiency of this plant is estimated to be 98 percent. This technology has already been applied in The Netherlands where 350,000 tons of soil has been treated. The waste gas purification system fully complies with the clean air regulations of TA-Luft.

Limitations: The economics of thermal destruction process represent their severest limitation. Application limited to volatile organic compounds. This mobile incinerator has only been tested on oils and coke facility soil. Incineration of other hazardous wastes may require additional flue gas cleanup (e.g., HCl from chlorinated HCs).

Economics: Costs for other applications will depend heavily n site conditions, but will reportedly be in the range of \$75 to \$125/ton of soil.

INTERNATIONAL TECHNOLOGY FACT SHEET (continued)

Status: The process represents proven technology. In the Boenen project, the erection of the rotary kiln plant will end in the spring of 1988. Commissioning is scheduled for March. RAG expects that operational experience and computational results will be available at the end of April, 1988.

Recommendations: The results of this NATO/CCMS study and other applications of RAG's mobile rotary kiln should be monitored.

Reference: NATO/CCMS Pilot Study; Demonstration of Remedial Action Technologies for Contaminated Land and Ground Water. 1st International Workshop, Karlsruhe, Federal Republic of Germany. March 16-20, 1987.

INTERNATIONAL TECHNOLOGY FACT SHEET

Process: Soil Cleaning by Extraction at the Pintsch Site

Type of Treatment: Physical

Country: Federal Republic of Germany

Institution/Contact: Dipl.-Ing. Kaufman
Der Senator Fur Bauund Wohnungswesen-HC
Wurttembergische Str. 6-1
D-1000 Berlin 31, FRG
Tel.: 030-867 7375

Wilko Werner
Managing Director
Harbauer GmbH & Co. KG
Ingenieurburo fur Umwelttechnik
Bismarckstrasse 10-12
1000 Berlin 12, FRG
Tel.: 030/341-1912

Function: Reduction of organic contaminants in soil by extraction.

Description: A research project has been authorized by the government to determine the effectiveness of extraction techniques. The basis of this soil decontamination is a multi-phase extractor. The soil is sifted, then pulverized using a double blade washer. This system has proved very suitable for decontamination of gravel and sand. The 4-mm sample is introduced into a pumping system and pumped via injector into the multi-phase extraction unit in a ratio of 1:3 (1/4 solids to 3/4 water). An intensive washing process takes place in the extraction unit by the addition of air. The soil/water mixture is then sent to a multi-hydrocyclone (separation diameter of 30 mm). If the sand is to be reused, the sand is removed via an upflow column. Particles up to 20 mm are removed in a wave plate separator and these fractions dried by vacuum belt filter, rewashed, and dried again. The smaller particles, less than 5 mm, are removed in a wastewater treatment system, then dried and either burned or encapsulated. This is required since the contamination is still present on particles of 5 mm or smaller size. The scum from this process is sent to the ground water treatment plant.

INTERNATIONAL TECHNOLOGY FACT SHEET (continued)

Performance: No data are available.

Limitations: Limitations are associated with the ability of water to successfully remove contaminants from soil, and the effectiveness of subsequent water treatment processes.

Economics: No cost data are available.

Status: This process is operational. Harbauer GmbH, a German cleanup firm, has developed this technique.

Recommendations: Performance should be monitored and new data from research studies evaluated. A site visit is recommended to gain performance data view of the operation and obtain economics data.

Reference: NATO/CCMS Pilot Study; Demonstration of Remedial Action Technologies for Contaminated Land and Ground Water. 1st International Workshop, Karlsruhe, Federal Republic of Germany. March 16-20, 1987.

INTERNATIONAL TECHNOLOGY FACT SHEET

Process: Ground Water Treatment at the Pintsch Site

Type of Treatment: Physical

Country: Federal Republic of Germany

Institution/Contact:		
Institution/Contact:	Dr. Melsheimer Der Senator Fur Stadtentwicklung Und Unweltschutz Lindenstr. 20-25 D-1000 Berlin 61, FRG Tel.: 030-2586 2515	Dr. Sonnen Harbauer GmbH & Co. KG Bismarckstr. 10-12 D-1000 Berlin 12, FRG Tel.: 030-341 1912

Function: This NATO/CCMS Pilot Study demonstration facility at the Pintsch site contains a large-scale plant for ground water treatment (Harbauer system).

Description: The ground water treatment facility is a full-scale plant based on results from a pilot plant constructed by Harbauer Engineering. Ground water contamination at the site measured in 1983 indicated concentrations as follows: hydrocarbons, up to 16,000 mg/L; oils, up to 1,000 mg/L; and phenols, up to 225 mg/L. In addition to the dissolved and undissolved oils and their compounds, the ground water was contaminated with volatile organic compounds (VOCs), primarily chlorinated hydrocarbons.

In order to meet the limits permitting discharge of the treated ground water to the Teltow Channel, a four-stage treatment plant was designed by Harbauer. The following discharge limits were required: mineral oils, less than 10 mg/L; VOCs, less than 25 mg/L; phenols, less than 5 mg/L; and PCBs, non-detectable.

As noted in the NATO/CCMS Pilot Study Report dated March 1987, the plant is unique in Europe due to its size and configuration. Ground water to the plant is pumped from nine, 40 m^3/h wells providing a maximum flow to the plant of 360 m^3/h. Each well had a mechanical oil separator, i.e., a Mopmatic-Wringer, for pretreatment. The recovered water contains benzene (up to 133 mg/L), phenols, and extremely variable concentrations of chlorinated hydrocarbons (primarily dichloromethane).

The Mopmatic-Wringer oil separators are unable to remove all of the oils from the ground water. An oil/water separator using the principle of flotation provides additional treatment. Each well can be independently connected to this process. In the inlet of the oil separator, recycled water saturated with compressed air is added and mixed in a pipe. The

Description (cont.): air-saturated water is released through a specially designed relief valve, whereby very small air bubbles are formed due to the pressure reduction. These bubbles adhere to the flocculate and provide a strong uplift. The rapidly rising flocculate is separated in the flotator and collected in the form of a floating sludge layer. The more slowly rising (smaller) flocculate is separated in the corrugated plate assembly where it flows in a countercurrent direction to the top, reaching the floating sludge layer. This floating sludge layer is removed by a thickener/stripper device to a sludge chamber. If there is no oil in the well, then the contaminated ground water directly enters the second treatment stage along with the discharge from the flotation oil/water separator unit.

The second treatment process is flotation. The water is equally distributed to three flotation units with a maximum capacity of 120 m^3/h each. Flow is controlled using manually-operated flow meters. The water is pretreated with $FeCl_3$ and polyelectrolyte in a tube flocculator. The resultant sludge is removed in a sludge pump and is expected to be destroyed by plasmac pyrolysis. Flotation removes all undissolved hydrocarbons to a level of 10 mg/L and approximately 10 to 20 percent of the VOC. The water then flows into a pump receiver tank and is fed to the third treatment stage by three pumps.

The third stage is an air stripping tower. The stripping tower is 2.5 m in diameter and 16 m high. It is equipped with two, 5-m-high packed columns and has an acid-resistant coating on the interior of the tower. The tower is designed for 360 m^3/hr of water and approximately 10,000 m^3/hr of air. VOCs, particularly toluene and benzene, are effectively removed using this method. The tower is designed for 90 percent removal of VOCs.

The air exhausted from the stripping tower and the flotation process are treated prior to discharge to the atmosphere. The humid air is desiccated by an air heater to a solvent recovery plant consisting of four activated carbon filters, each with a capacity of 3,800 m^3/h. The filters are regenerated using steam; the steam is condensed and sent to a heavy fraction and volatile separator. The recovered hydrocarbons are sent to a 20-m^3 solvent tank. The solvents are tested to determine proper disposal (i.e., high temperature combustion if PCBs are detected; otherwise, solvent recovery). During the air stripping, metals, particularly iron and manganese, contained in the water oxidize resulting in a cloudy, brown water. This water flows to the fourth treatment stage.

The water is sent to a classic multilayer gravel filter to remove the metal precipitates. This process is followed by a six-stage activated carbon filter. Six stages were selected to allow use of different activated carbon types to effectively treat the different combinations of hydrocarbons. This flexibility is necessary because the service time of

Description (cont.): the activated carbon depends on the relevant content of the hydrocarbon components in the water, in this case primarily phenol and dichloromethane. The service time, in turn, has a considerable effect on operating cost, since presently the regeneration of carbon-containing PCBs and polyaromatics is not possible. The possibility of microbiological regeneration of activated carbon will be investigated in the future. The treated water, which is almost of drinking water quality, is discharged to the Teltow Channel following final monitoring.

Performance: As noted, the treated water is almost of drinking water quality.

Limitations: Limitations inherent to the potential of the treatment processes employed (flocculation, stripping, adsorption) can be anticipated.

Economics: Cost data were not available.

Status: The ground water treatment facility is operational.

Recommendations: This plant represents application of existing technology to cleanup of organic contamination from ground water and should be monitored carefully. A site visit is recommended to obtain information on performance and economics.

Reference: Brown, Margaret. Correspondence of October 1987.

NATO/CCMS Pilot Study; Demonstration of Remedial Action Technologies for Contaminated Land and Ground Water. 1st International Workshop, Karlsruhe, Federal Republic of Germany. March 16-20, 1987.

INTERNATIONAL TECHNOLOGY FACT SHEET

Process: Remediation of Diesel Fuel Contamination Using Ozone

Type of Treatment: Chemical/Biological

Country: Federal Republic of Germany

Institution/Contact: Federal Ministry for Research & Development
Dr. Peter Werner
DVGW-Forschungsstelle am
Engler-Bunte-Institut der Universitat Karlsruhe
Richard-Willstalter-Allee 5
D-7500 Karlsruhe 1, FRG
Tel.: 0721/608-2589

Function: Purification of ground water by oxidizing organic water contaminants from diesel fuel with ozone and enhancing subsequent biological degradation. Process operated by the City Waterworks of Karlsruhe.

Description: This process was placed into operation at Karlsruhe in 1980. The process is based on experience gained in Mulheim/Ruhr using ozone-enhanced biological purification and activated charcoal. In this process the water from the most polluted well is treated with ozone and infiltrated again through the contaminated soil upstream of the well. The infiltrated water provides a barrier for further infiltration of contaminants. Reportedly, this ozone treatment leads also to better biodegradation of the organic pollutants and subsurface soil contamination. The water is pumped out of the other clear-wells and distributed without any further treatment, even without chlorination. The Federal Ministry for Research and Development has contributed to the development of this new technology.

References cited by Nagel include:

- Sontheimer, Heilker, Jekel, Nolte, Vollmer: The Muhlheim process. J. AWWA 70, 1978, No. 7, p. 393-396.
- Aquatechnique Sierra S.A., Chippis/Schweiz. Device for the Chemical Decontamination of Ground Layers and/or Water Polluted with Organic Substances. Patent BE 18381.

Performance: The literature reported that analytical data prove that this process leads to an excellent ground water quality.

Limitations: Only organic contaminants can be treated with this technique.

Economics: No cost data available, but it is stated that the process could be very economical.

Status: The process had been in operation for 1.5 years at the time the paper was presented which was in 1982.

Recommendations: Monitor current applications of this technology through discussions with Dr. Werner.

Reference: Nagel, G. et al. "Sanitation of Ground Water by Infiltration of Ozone-Treated Water." GWF-wasser/abwasser, 123 (8): 399-407. 1982.

INTERNATIONAL TECHNOLOGY FACT SHEET

Process: Klockner High-Pressure Water Jet Soil Washing System

Type of Treatment: Physical

Country: Federal Republic of Germany

Institution/Contact:
Dr. Hans-Jurgen Heimhard
Klockner Oecotec GmbH
Neudorfer Str 3-5
D-4100 Duisburg 1
Tel.: 0203-182420

Function: High-pressure water jets are used to remove pollutants from soil particles.

Description: This process is designed to clean excavated contaminated soil by contacting the soil with water in a high-pressure jet pipe - the core of the high-pressure soil washing unit. The contaminated, prehomogenized soil is drawn into the unit by the suction forces created by water flow through a number of nozzles arranged circularly and focused at a concentric point within the pipe. At the focal point, the forces produced by a pump pressure of up to 350 bar (1 bar = 1 million dynes/cm^2) are reportedly so strong that pollutants adhering to the soil grains are blasted from the surface. The turbulent flow created by the soil washing process ensures that each soil grain is washed from all angles. Further, the duration of treatments can be shortened or extended by adjusting the angle of the jets, and thereby the length of the jet cone.

Pollutants removed from the soil are transferred into the process water, with volatiles further transferred into the air stream drawn into the unit along with the contaminated soil. Subsequently, the air stream is separated and treated to remove the pollutants. Treatment of the process water involves removal of contaminated fine particles and water insoluble pollutants from the bulk of the treated soil by sedimentation and filtration processes. The fine particle, pollutant-containing concentrate constitutes a filter cake solid residue representing 15 to 20 percent of the treated soil. This residue will require further treatment. The process water released from these residues is recirculated and fed back into the jet pipe. The bulk of the treated soil with soil particle size distributions now set above 0.03 to 0.06 mm diameter can be treated to further reduce residual pollutants. Reportedly, the removal of the fines from the bulk of the soil enhances permeability and the biological degradation of residuals from the soil.

Description (cont.):

The soil that had been subjected to the washing process could be put back in place. Work is underway to build children's playgrounds and a park on a Berlin site remediated by high pressure soil washing.

Performance: According to Klöckner, the process has been used to clean approximately 100,000 tons of soil with different pollutants and has proven itself to be economical and effective. Pollutant removals from soil of 95 to 99 percent have been obtained. The capacity of this technique varies between 15-40 ton/hour, depending on the clay content of the soil.

Limitations: Large soil particles (in excess of 10 cm diameter) must be removed by pretreatment. Small particles (less than 0.03 to 0.05 mm diameter) are not cleaned effectively by the water jets. These problems may be solved by the use of a newly developed pneumatic flotation device.

Economics: The prices lie between DM 140 and DM 200/ton of feed depending on the contamination and the soil type and structure. This includes wastewater and exhaust air processing and pollutant disposal, i.e., for a complete treatment service.

Status: This patented high pressure soil washing process is being offered by Klöckner Environmental Engineering of the Federal Republic of Germany. The process is to be used in a NATO/CCMS Pilot Study demonstration of remedial action technologies at a former scrap metal site, Berlin-Chaelottenburg, Berlin, Federal Republic of Germany, in 1987. The study, using a 30 ton/hour onsite mobile unit, became operational in December 1986, but was shut down due to bad weather conditions until February 1987.

Recommendations: Further information concerning limitations, performance and cost is needed for the full range of contaminants and soils. Monitor results.

References: Brown, Margaret. Correspondence of October 19, 1987.

NATO/CCMS-Pilot Study: Demonstration of Remedial Action Technologies for Contaminated Land and Ground Water. 1st International Workshop, Karlsruhe, Federal Republic of Germany. March 16-20, 1987.

Process: The LECO System using DCR, for Solidifying Special Wastes and Stabilizing Contaminated Soils

Type of Treatment: Chemical Solidification

Country: Federal Republic of Germany

Institution/Contact: Dr. Hartmut U. Wiedemann and Klöckner Oecotec GmbH
Gesellschaft fur Rohstaffruckgewihrung
und Umweltsanierung
Neudorferstrabe 3-5
D-4100 Duisburg 1, Federal Republic of Germany
Tel.: (0203) 181

Function: To increase chemical reactivity of toxic compounds by dispersion.

Description: The technology has been used since 1975. A mobile unit was reportedly developed in the early 1980s. Solidification of residues containing mineral oils, including restoration work for slurry ponds and contaminated soils by a process which uses as an additive quicklime (CaO) treated with retarders (hydrophobic agents). The process has been marketed under the description "Dispersion by Chemical Reaction" (DCR) by Buchen & Leo, Weserstrasse 84, 2820 Bremen 70.

The reagents are worked into the waste over a large area with heavy-duty earth scrapers. The water present in the slurry or soil reacts with the CaO, or evaporates in the heat of the reaction. Non-volatile substances are absorbed and distributed in the easily compactible material. Oily sludges are thus transformed into road building materials.

Performance: 14 contracts carried out in Europe between 1975 and 1980. Table 1 shows the values of bearing strength derived from the activities to date.

TABLE 1. BEARING STRENGTHS IN ACCORDANCE WITH DIN 18.134 (PLATE BEARING TEST) ACCORDING TO GERSCHLER [38]

Place	E(v1)	E(v2)
Dollbergen	0.83 kN/sq cm	2.56 kN/sq cm
Dollbergen[a]	1.36	4.22
Marchegg	4.95	10.78[b]
Oyten	2.65	6.22

[a] 0.6 M under bed level.
[b] Calculated from E(v1) x 2.2.

Limitations: Only practical on large areas (50 x 100 M). Dust formation can be a problem.

Economics: No data available.

Status: A mobile treatment plant was designed in collaboration with the Austrian company, Voest-Alpine. The LECO system, as it is called, consists of two standard containers, a mixer and a reactor. The system can be easily transported, assembled and dismantled, so it can be quickly brought into use for oil accidents. In the mixing unit, the wastes are covered with the necessary amount of additive and intemately mixed with a mixer specially designed for this purpose. The materials are then led into the reaction chamber, where the reaction proceeds on slowly moving belts. The powdery reaction product can be stored temporarily until it can be used for road construction or other purposes.

Anticipated throughput: 30 m^3/hr

Recommendations: Further research needed to better characterize this technology.

References: Klöckner Oecotec. DCR-Technology. Company brochure describing DCR chemical technology. May 19, 1987.

Steif, Klaus. Note to Don Sanning describing DCR process. Undated.

Wiedemann, Dr. Hartmut U. Process for the Solidification of Hazardous Wastes and Stabilization of Contaminated Soils: State of Knowledge and Feasibility. Umweltbundesamt-Bevichfe 1:29-33, 128-42. 1982.

Wiedemann, Dr. Hartmut U. Umweltbundesamt. Process for Solidifying Special Wastes and Stabilizing Contaminated Soils - State-of-the-Art and Possible Applications. January 1982.

INTERNATIONAL TECHNOLOGY FACT SHEET

Process: Biological Remediation of Soil and Water Using the IAT-Biosystem

Type of Treatment: Biological

Country: Federal Republic of Germany

Institution/Contact:

Mr. Lissner, Mr. Henke
Umweltschutz Nord GmbH
Bergedorfer Str. 49
2875 Ganderkesee 1, FRG
Tel.: (04222) 1023

Function: Biological treatment of mineral oil/hydrocarbon contaminated soil.

Description: This system converts aliphatic or aromatic hydrocarbons to H_2O and CO_2 and may be used with a range of soils (mother earth, sand, gravel and stone). Substrate is Terra C-Type 12, OX.45, a natural organic substrate with adapted microorganisms, enzymes, and nutrients. Thirty-three basic bacteria from 136 collective microorganisms are available. Process includes: analysis of the soil to identify soil characteristics, contaminants present, concentration of pollutants, and other virus/bacteria present which may be harmful to the selected bacteria; preparation of beds; mixing bacteria with the soil (this and selection of the substrate are the most critical factors); and laboratory oversight and analysis as destruction proceeds. Transformation of hydrocarbons takes place under primarily aerobic conditions.

Performance: Complete destruction takes place in 12 to 24 months, depending on factors cited under limitations section. Figure 1 shows the performance of the IAT-Biosystem with respect to initial concentrations of hydrocarbon.

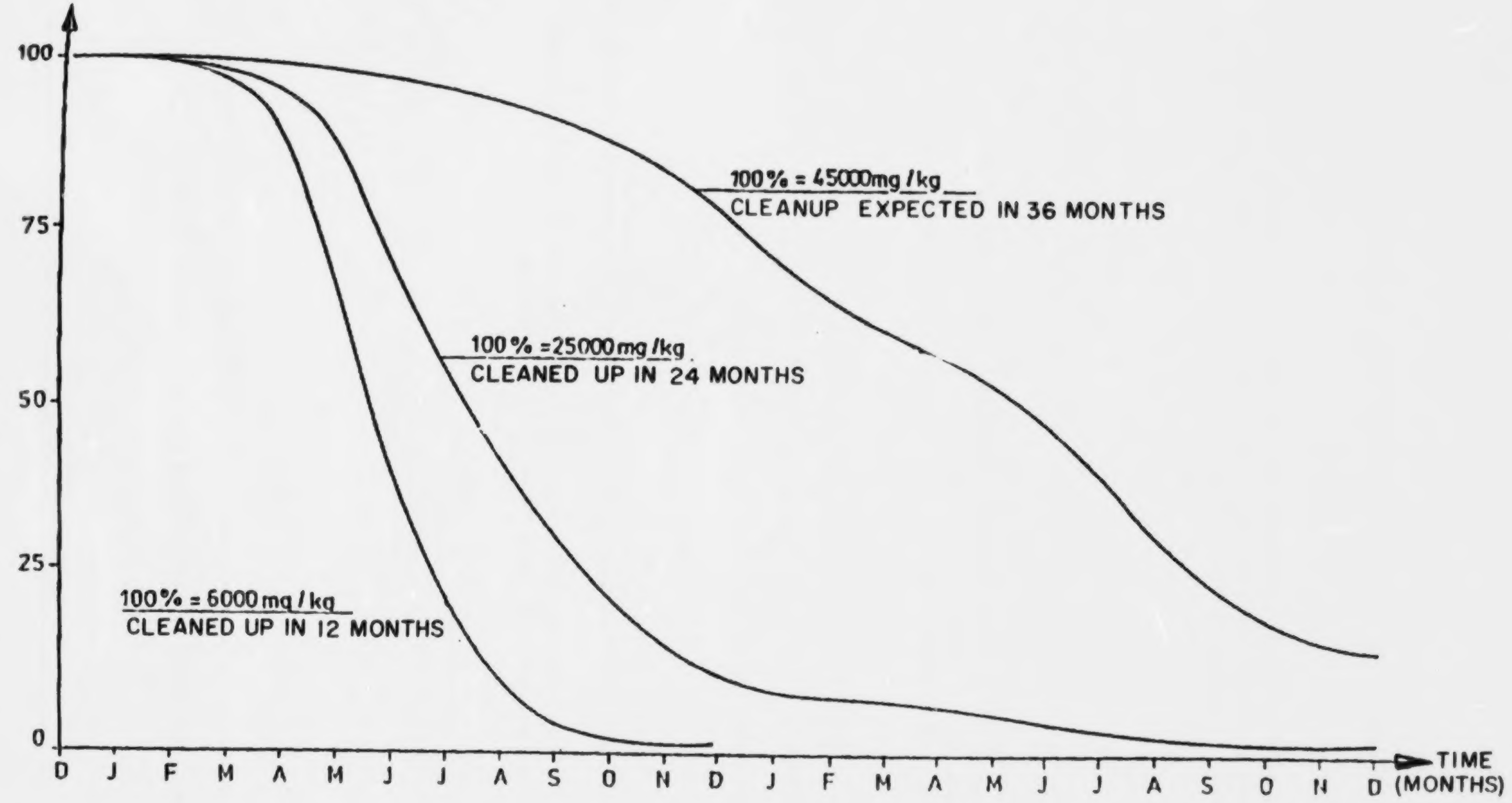


Figure 1. Performance of the IAT-Biosystem based on initial concentrations.

INTERNATIONAL TECHNOLOGY FACT SHEET (continued)

Limitations: No chlorinated compounds can be destroyed by this method. Time required depends both on starting concentration and time of year (temperature). Concentrations of pollutant (dry basis in soil) of more than 25,000 mg/kg increase time dramatically.

Economics: Treatment costs are reportedly $65-$110/ton treated. These costs are comparable with thermal treatment and landfilling costs with the added advantage that complete destruction is achieved, and there is no secondary waste generated and no future risk to the environment.

Status: Has been used in Europe on a full-scale basis.

Recommendations: Should be studied further to obtain update performance and economics results. A site visit is recommended.

Reference: Brown, Margaret. Correspondence of October 19, 1987.

INTERNATIONAL TECHNOLOGY FACT SHEET

Process: Lab Cultivation of Specific Microorganisms for the Decontamination of Abandoned Sites

Type of Treatment: Biological

Country: Federal Republic of Germany

Institution/Contact: Institute fur Umweltanalytik und Biotechnologie GmbH

Function: Acceleration of biological degradation of pollutants and combined/alternating use of mechanical and biological methods for onsite treatment.

Description: The project is divided into two phases: the first phase is the selective accumulation (cultivation) in the laboratory of an adapted micro-flora taken from the contaminated soil itself for routine use in future cases of damage, and trials on a semi-commercial basis of different methods of influencing the degradation of pollutants in soil. The second or soil cleanup phase has two possibilities: in situ degradation by enhancing conditions conductive to the organisms present (increasing the concentration of nutrients and innoculation with starting cultures) or onsite removal of pollutants through leaching with degradation in separate stages by selected microorganisms.

The project has received a Federal Research Grant of 40 percent of total costs in the amount of $220,000.00.

Performance: Project is progressing. No results available as yet.

INTERNATIONAL TECHNOLOGY FACT SHEET (continued)

Limitations: None noted at present.

Economics: Costs should be competitive with other methods.

Status: Research is in progress; results will be available later in 1988.

Recommendations: Have further discussions with Umweltbundesamt project director to update information regarding performance, limitations and economics.

Reference: Brown, Margaret. Correspondence of October 19, 1987.

INTERNATIONAL TECHNOLOGY FACT SHEET

Process: Shell BIOREG Process for Onsite Cleanup of Contaminated Soil

Type of Treatment: Biological

Country: Federal Republic of Germany

Institution/Contact: Herr Gebhardt
Deutsche Shell

Function: Onsite cleanup of hydrocarbon and other similar pollutants.

Description: Bacteria were developed and applied to virgin oils and later adapted for used oils. Substrate is milled pine bark, which provides a medium where bacteria and pollutants interact (porosity, pollutant affinity, interaction with bacteria, etc.), and also enhances bacterial development.

Bacteria and substrate are mixed with the soil in beds and provided with aeration and, where necessary, a leachate collection system and liner. Shell believes their aeration techniques and substrate mixture are the keys to this treatment.

Performance: Regeneration time depends on the levels and types of pollutant present. Critical factors are the mixing of the substrate with soil and bacteria in the beds, the watering of the beds, and bed height and size. Reduction of approximately 2,300 kW/kg to 300 kW/kg in 17 months was observed.

Limitations: Preliminary tests determine the applicability of biological treatment on a site-by-site basis, and what adjustments (pH, etc.) are necessary to modify conditions for maximum bacterial activity. As for all biological treatments, no chlorinated compounds can be treated.

Economics: Treatment reportedly costs \$55 to \$80/cubic meter for normal/average pollutant conditions and \$90 to \$150 for difficult sites.

Status: Successfully in use.

Recommendations: Obtain more details on limitations and useful applications of this process through discussion with developers. Monitor current status.

Reference: Brown, Margaret. Correspondence of October 19, 1987.

INTERNATIONAL TECHNOLOGY FACT SHEET

Process: The EFEU Flush Gas Distillation of Contaminated Earth

Type of Treatment: Thermal

Country: Federal Republic of Germany

Institution/Contact: EFEU GmbH
Mr. Michel-Kim
Ackerstrasse 71-76
D-1000 Berlin 65
Tel.: 469-4672

Function: A more efficient technique of thermally decontaminating soils.

Description: This method has the advantage that energy consumption is relatively lower (soil is only heated to 400°C), cracking can be avoided and, therefore, carbon can be produced and the residue can be easier to incinerate. The system has four parts:

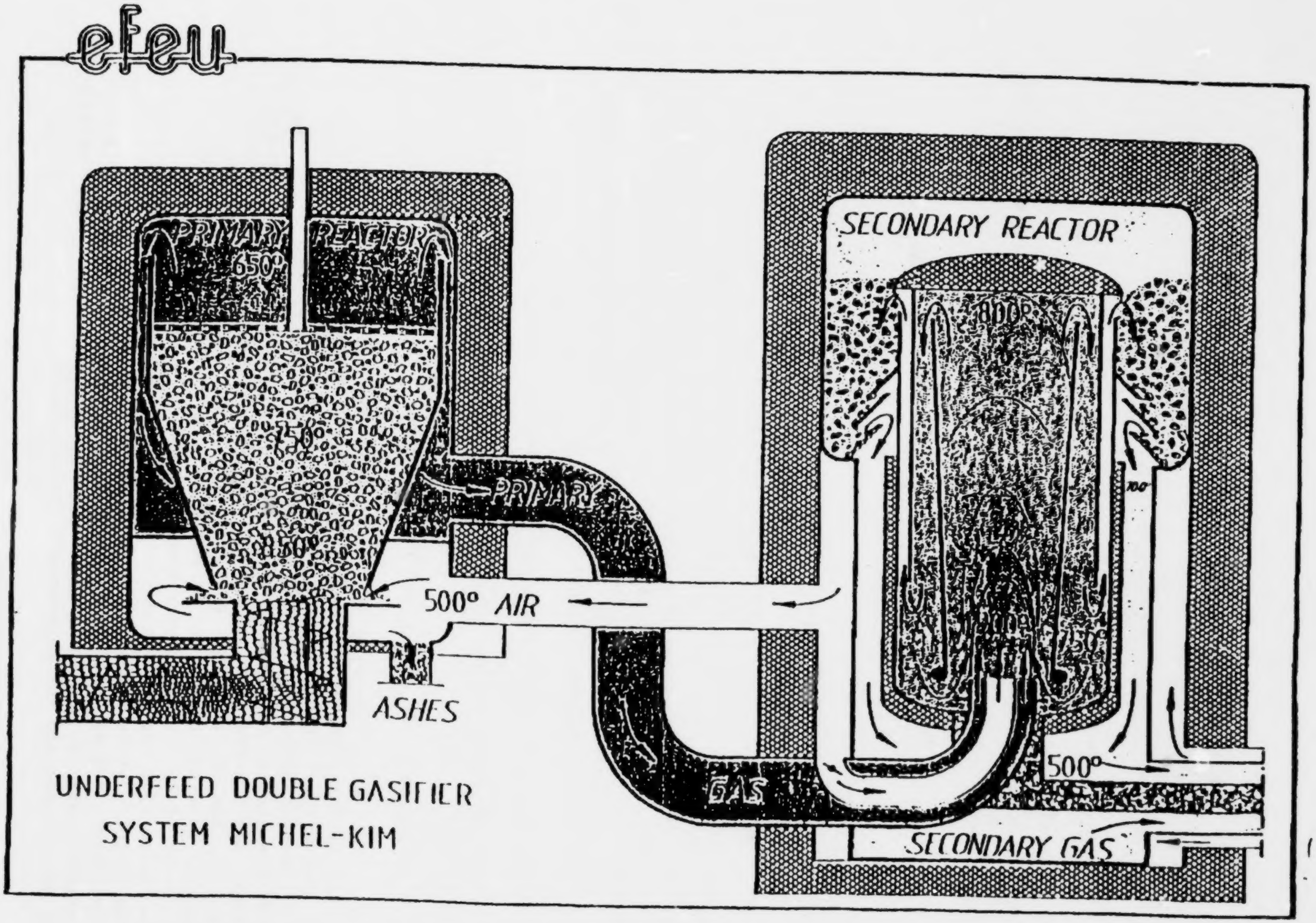
1. Rotary kiln (or multiple hearth) as the distillation vessel. Here, flush gases enter after generation in,

2. The gasifier, where gases are produced;

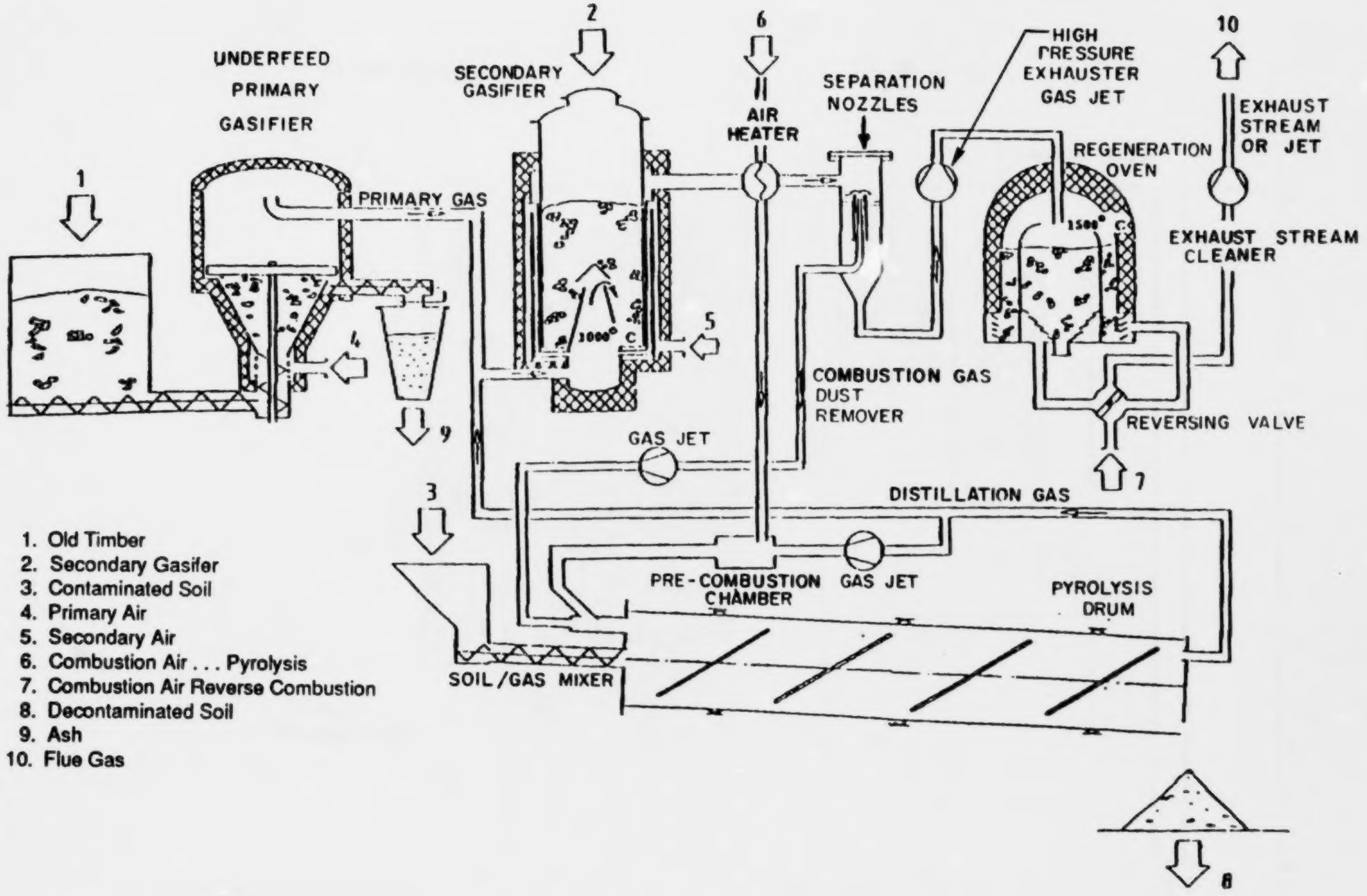
3. Hot gas precipitator - for removal of dust in the gases without cooling; and

4. Incinerator for burning of the residues.

Direct heating of the kiln with flush gases has the advantage of providing for dust removal while avoiding the extra energy consumption necessary for heating of the kiln walls. Direct heating also has the advantage of producing a very concentrated distillate. There are three possible choices for the heating medium which were considered: water vapor, inert gases, and reducing gases. Water vapor is a good energy carrier, but requires more energy to heat. Inert gases may not be totally pure/inert and free or would interfere with stochiometry of process. Reducing gases were therefore chosen. They are easily generated (and recycled) and the process can be run at 300 to 500°C or 700 to 800°C where high boiling hydrocarbons are present. In a reducing atmosphere, the production of undesirable polycyclic by-products is also reduced (refer to the following three diagrams for a better understanding of the process and the apparatus).


efeu
PRIMARY REACTOR
650°
PRIMARY
500° AIR
ASHES
GAS
SECONDARY REACTOR
800°
500°
SECONDARY GAS
UNDERFEED DOUBLE GASIFIER
SYSTEM MICHEL-KIM

EFEU flush gas distillation system.


UNDERFEED
PRIMARY
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PRIMARY GAS
Silo
1000° C
1500° C
AIR
HEATER
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NOZZLES
HIGH
PRESSURE
EXHAUSTER
GAS JET
REGENERATION
OVEN
EXHAUST
STREAM
OR JET
EXHAUST STREAM
CLEANER
COMBUSTION GAS
DUST
REMOVER
REVERSING VALVE
GAS JET
DISTILLATION GAS
PRE-COMBUSTION
CHAMBER
GAS JET
PYROLYSIS
DRUM
SOIL/GAS MIXER
1
2
3
4
5
6
7
8
9
10
1. Old Timber
2. Secondary Gasifer
3. Contaminated Soil
4. Primary Air
5. Secondary Air
6. Combustion Air . . . Pyrolysis
7. Combustion Air Reverse Combustion
8. Decontaminated Soil
9. Ash
10. Flue Gas

Figure 2. Flow schematic of the EFEU flush gas distillation system.

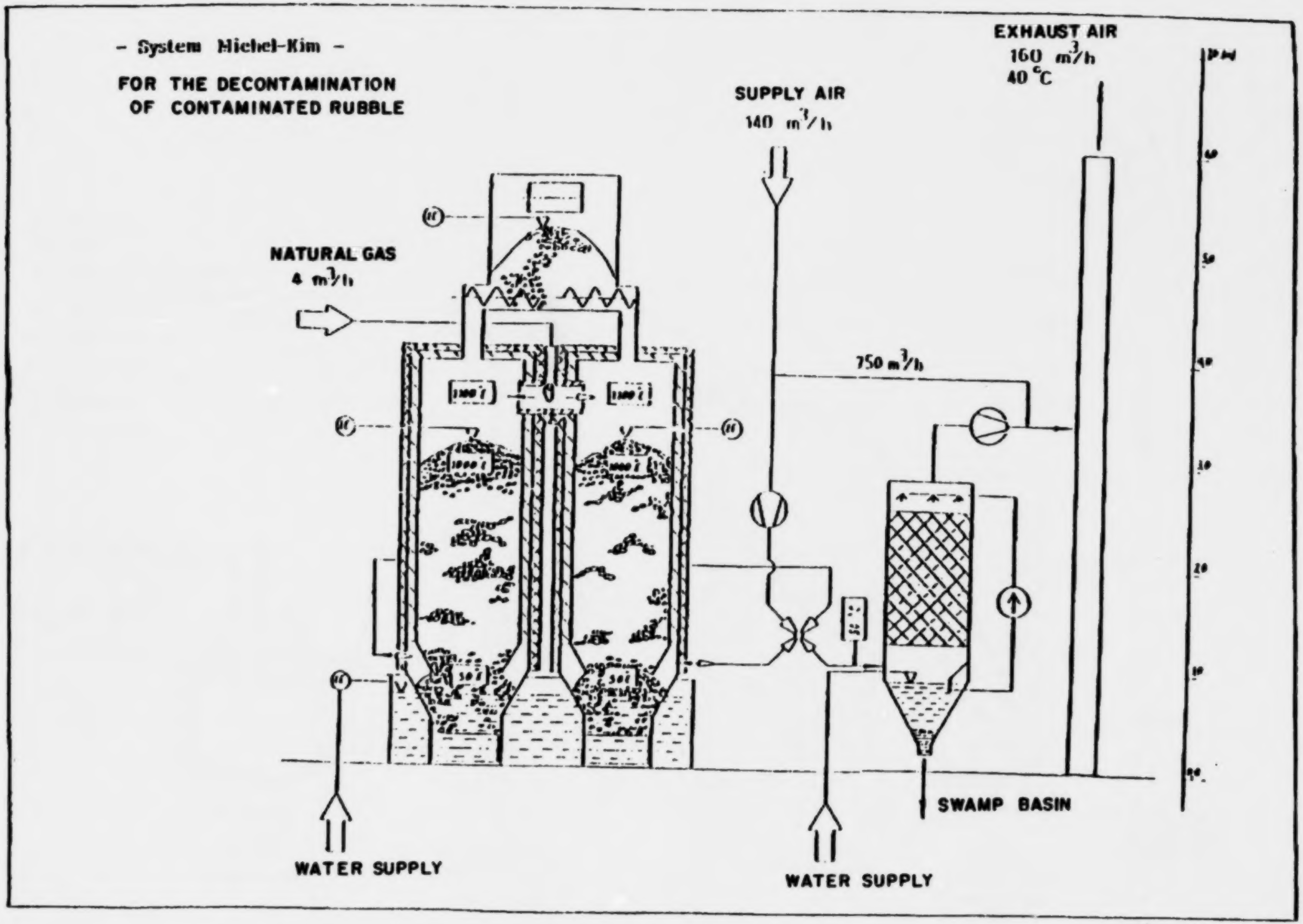
- System Michel-Kim -
FOR THE DECONTAMINATION OF CONTAMINATED RUBBLE
SUPPLY AIR
140 m³/h
EXHAUST AIR
160 m³/h
40 °C
NATURAL GAS
4 m³/h
750 m³/h
SWAMP BASIN
WATER SUPPLY
WATER SUPPLY

Figure 3. Thermal units of the EFEU gas distillation system.

INTERNATIONAL TECHNOLOGY FACT SHEET (continued)

Performance: No actual use to date. A patent has been granted and the engineering details are completely worked through.

Limitations: Substances must be distillable. Best used for low boiling hydrocarbons or where there is a chance of high boilers which, with the high temperature phase (700 to 800°C), can be handled with lower energy consumption than in an incineration process. This technology can have difficulties with pasty soils (which are difficult to heat evenly) or soils having uniform or fine consistency (which produced excessive dust). Sandy soil is excellent because of its heat transfer abilities.

Economics: No actual data. The energy saving is the basic premise for the process, which could be cheaper than incineration.

Status: EFEU GmbH is seeking a cooperation partner to construct the unit.

Recommendations: Monitor the status and results of this technology; a site visit is recommended.

Reference: Brown, Margaret. Correspondence of October 19, 1987.

INTERNATIONAL TECHNOLOGY FACT SHEET

Process: Onsite Soil Cleaning Using the "Oil CREP System"

Type of Treatment: Physical/Chemical

Country: Federal Republic of Germany

Institution/Contact:
Fred Gunshera
TBSG Industrievertratungen GmbH
Langenstrasse 52-54
2800 Bremen 1, FRG
Tel.: (0421) 17 63 267

Function: Removal of oil from soil using a mobile cleaning system. A patented solution is used to wash out oil, forming a separable emulsion and allowing recycling of the water phase.

Description: System is a basic washing procedure, but uses the product Oil CREP I (Cleaning, Recycling, Environmental Protection) which forms a separable emulsion with water and therefore, allows the recycling of the water layer. Oil CREP I itself is not toxic, contains no aromatics, is not a dispersion agent, leaves the basic structure of the pollutant oil, and has the "Environment Friendly" seal of the German environmental agency.

The system operates on the basic principle of adsorption and cold water washing with high pressure to create a separable emulsion. This allows skimming of the oil layer and after clarification, return of clean wastewater to the wastewater system without special treatment. Heavy metals are removed as hydroxides. Process steps include centrifuge, oil removal, pH adjustment, detoxification through oxidation or reduction, heavy metal precipitation, water clarification, and neutralization through ion exchange.

Performance: Pilot plant was successfully operated and in 1985, a 20 ft mobile container unit was built. This unit has been in use with success since then. Bremen University has conducted independent tests on one site and found that sand contaminated with 14,000 ppm oil was reduced to 190 ppm, which is well below the 300 ppm level for reuse of sand in the FRG. Efficiency was 98.7 percent.

INTERNATIONAL TECHNOLOGY FACT SHEET (continued)

Limitations: Soil must be conditioned to reduce particle size to 60 mm.

Economics: Exact data not available, but considered a proven system.

Status: System is now in use in Europe.

Recommendations: Site visit recommended to obtain performance and economics data and to view operation if possible.

Reference: Brown, Margaret. Correspondence of October 19, 1987.

INTERNATIONAL TECHNOLOGY FACT SHEET

Process: Thermal Cleaning of Soils Contaminated Primarily with Organics

Type of Treatment: Thermal

Country: Federal Republic of Germany

Institution/Contact:
Dipl.-Ing. M.F. Nussbaumer
Ed. Zublin AG
P.O. Box 2985
7000 Stuttgart 1, FRG
Tel.: (0711) 788-3231

Function: Cleanup of soil contaminated with organics, including aromatic hydrocarbons and high boiling point substances (benzole and heavy metals such as mercury; also cyanide).

Description: This program included a theoretical examination of the type of furnace to be used (sinter belt, fluidized bed, or rotary kiln). Rotary kiln was selected and a small-scale unit was built for 200 to 400 kg/hr. Flue gas cleanup included thermal post combustion, dry adsorption by lime hydrate, and a multi-stage filter system. Following successful operation of this unit a pilot-scale unit will be developed (5T/hr) and finally, a production scale unit will be built with a capacity of 20,000 m^3 annually. To date, the project has received a 50 percent funding grant from the Federal Research Ministry in the amount of $2.1 million. Total project cost is approximately $5 million.

The key factor is control of operating conditions so that high boiling point and difficult to burn substances are oxidized (e.g., coal, tar, oil, cyanide, and heavy metals). This technology is based on the rotary kiln, but is essentially new incineration design.

Performance: A small unit (200 to 400 kg/hr) has been successfully operated using a wide range of soil types. Soil samples underwent combustion at temperatures of up to 1100°C. Flue gases were post-combusted at 1200°C. Analysis of soil showed no organic pollutants present and emissions were well below TA Luft requirements. Residues are reported as follows:

CO	11 ng/Nm^3	dust 3 ng/Nm^3
C_xH_x	3.4	
HF	0.02	
HCl	0.6	
SO_2	none measured	
NO_x	52.6	

INTERNATIONAL TECHNOLOGY FACT SHEET (continued)

Limitations: No special limitations reported.

Economics: 1,000 KCal of energy were used per kg of earth. Costs for the 5 ton/hr unit (36,000 ton/yr) are reportedly approximately $90 to $125/ton.

Status: A 5 ton/hr unit is under construction and after its successful operation, a full-scale incinerator will be built.

Recommendations: Technology is feasible and further study would be useful. Regulatory officials in the Federal Republic of Germany believe this one is worthwhile. Check on performance with respect to the high boiling point substances this technology was meant to handle, e.g., cyanide, mercury, and heavy metals.

Reference: Brown, Margaret. Correspondence of October 19, 1987.

INTERNATIONAL TECHNOLOGY FACT SHEET

Process: Chlorinated Hydrocarbon Remediation by High-Pressure Suction

Type of Treatment: Physical

Country: Federal Republic of Germany

Institution/Contact: Dr. Mathias Stein and Dr. Peter Wolff
Hannover Umwelttechnik GmbH
Impexstrasse 5
6909 Waldorf, FRG
Tel.: 49-62279051

Function: Removal of highly volatile hydrocarbons from unsaturated soils by suction at an existing site.

Description: For saturated soils, water removal by hydraulic systems can be used. For unsaturated soil, excavation or artificial saturation methods must first be employed prior to cleanup; however, these methods are infeasible where the area of contamination occurs under existing structures or industrial facilities. The saturation/excavation and hydraulic methods are also costly, and the soil or water still requires further cleanup. The method described here allows rapid onsite cleanup without secondary waste materials. The actual test site was a former metal finishing works. Trichloroethene at levels up to 14,000 mg/m^3 in the soil air, and 28 mg/kg in the soil was found.

For cleanup, a single pipe of 150 mm diameter was installed to a depth of 6 meters, which was 0.5 m above the ground water level at 6.5 m. A suction of 400 m^3/hr (STP) with a differential pressure of 0.02 bar was applied at varying depths. To determine the area of influence of the single suction pipe, smoke cartridges were planted over the entire landfill area (35 m radius). Suction was detected over the entire 35 m radius. Actual area is estimated to be greater (probably more than 50 m). In this application no air emissions problems were incurred because pollutant level was within standards. If such problems occur, an activated carbon filter system could be installed.

INTERNATIONAL TECHNOLOGY FACT SHEET (continued)

Performance: In 4 months, 70 kg of chlorinated hydrocarbons were removed. As a side effect, one ground water monitoring well showed a drop in the initial ground water concentration of 5,400 mg/m^3 of water to 205 mg/m^3 after 1 month. However, this data was contradicted by a second well where the concentration increased.

Limitations: Site must be unsaturated. Contaminant must be a highly volatile compound. Results will vary with volatility and soil type.

Economics: Data could not be obtained in short time frame.

Status: Pilot plant has been operational in Rhein-Necar-Raum since 1984, and technology has been applied at other sites including one with highly-contaminated peat.

Recommendations: Site visit recommended to see how this operation differs from U.S. technologies. Follow-up on any theories regarding ground water remediation. Operational modes and duration of operation should be the focus of the site visit, as well as economics.

Reference: Brown, Margaret. Correspondence of October 19, 1987.

INTERNATIONAL TECHNOLOGY FACT SHEET

Process: Use of Specially-Adapted Microorganisms to Clean Contaminated Soil

Type of Treatment: Biological

Country: Federal Republic of Germany

Institution/Contact: Dr. Schussler
BIODETOX

Function: Onsite cleanup of soil contaminated with heating and diesel oil, gasoline, kerosene, phenols and formaldehyde.

Description: Uses adapted, but not genetically-altered bacteria for the destruction of heating and diesel oil, gasoline, kerosene, phenols and formaldehyde. Four methods of introducing the bacteria are used: foam application to the surface 40 cm deep, surface tilling (2 m deep), deep earth (to 20 m), and ground water. Studies have been done with bedding experiments to determine optimum conditions for bacterial activity.

Performance: A waste site where soil is being treated in lots of 1,000 m^3 has been reduced in the first test run from 12,000 mg/kg to 600 mg/kg in 6 weeks, and improved in the second test to 300 mg/kg in 4 weeks. The third test is underway.

Scrap automobile site was cleaned (1.4 hectare size) with hydrocarbon pollution to 0.6 m deep. 9,000 mg/kg was reduced in 6 weeks to 600 mg/kg.

Cleaning of gravelly soil between railroad tracks using foam method removed more than 90 percent of pollutant in 4 weeks.

Limitations: Typical for biological; no chlorinated compounds can be degraded and heavy metals must be low.

Economics: No cost data available from literature, however, system is noted as similar in price to conventional cleanup methods (excavation/landfill).

Status: In use in Europe.

Recommendations: Update the status of these projects. Determine most effective techniques found in FRG.

Reference: Brown, Margaret. Correspondence of October 19, 1987.

INTERNATIONAL TECHNOLOGY FACT SHEET

Title: Root Zone Bed Treatment of Organics

Type of Treatment: Biological

Country: Federal Republic of Germany

Institution/Contact:	Professor Lickuth University of Kassel Federal Republic of Germany	Hugh Hoather, Spokesman Cheshire County, United Kingdom

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Function: Treating organically polluted wastewater using the biological activity of the root and soil zone of reed beds.

Description: In the soil, wastewater flows along the annular spaces around the rhizomes of reeds. Bacteria found on these reeds are able to biochemically oxidize impurities. The reeds provide a constant source of dissolved oxygen using the root zone, or rhizosphere, through the leaves and stems.

Depending on the topography, pumping may be required or the treatment process may be enhanced by recirculating the effluent. A "wetland habitat" can thus be created which can remain operational with little maintenance long after the site stops accepting wastes.

Performance: Reduces BOD by 95 percent to levels around 20 mg/L or less. Nitrification and de-nitrification can also reportedly be achieved.

Limitations: This technology may be effective in the United Kingdom where co-disposal means relatively low concentrations of toxic constituents, but elsewhere, where concentrations are high, this solution may not be effective enough.

Economics: Data on economics are not available.

Status: A research program involving a large-scale experiment with a root zone system for treating leachate was developed by Professor Lickuth in the Federal Republic of Germany. Cheshire County in the United Kingdom is currently conducting a reed experiment at the landfill site at Danes Moss, Macclesfield. In September 1987, the reeds had been planted and after 6 months the leachate will be introduced. Depending on climate and weather conditions, the Cheshire County Council, who is running the research program, predicts 3 years will be necessary to cultivate the reeds.

Recommendations: Update status.

Reference: Shimell, Pamela B. "British Link Conservation to Solving Landfill Problems." World Wastes. pp. 42-43. September 1987.

INTERNATIONAL TECHNOLOGY FACT SHEET

Process: Ekokem Commercial TSDF-Finland

Type of Treatment: Thermal and Physical-Chemical

Country: Finland

Institution/Contact: A. Kavonius and Ekokem Oy Ab
Riihimaki, Finland

Function: Commercial hazardous waste treatment, storage and disposal facility.

Description: Ekokem's hazardous waste treatment plant consists of an incineration plant with an annual capacity of 35,000 tons of organic waste, and 15,000 tons of liquid waste; a physical-chemical treatment plant with a capacity of 3,000 tons; a landfill capacity of 20,000 tons; a receiving station with a capacity of 54,000 tons (of which 16,500 tons are for barrels and containers); and a wastewater treatment plant capable of processing 50,000 tons of wastewater (all capacity data per annum).

Performance: Data not available.

INTERNATIONAL TECHNOLOGY FACT SHEET (continued)

Limitations: Not available.

Economics: Investment costs of the plant during the construction were FMK 227 million without interest expenses. Hazardous waste treatment costs at Ekokem are reported to be comparable to those in Sweden. In most cases, it is more economical for industries to take their hazardous wastes to Ekokem than to build their own treatment plants.

Status: Appears to be a new facility (1986).

Recommendations: No further action recommended.

Reference: Chemical Engineering Abstracts, No. 2, No. 695. 1987.
(Kavonius, A. Kem. - Kemi., 1986, vol. 13 (11), 970 - 973 (Finnish).)

INTERNATIONAL TECHNOLOGY FACT SHEET

Process: Rhône-Poulenc/Vicarb Process for Valorization of Chlorinated Résidues-(VCR)

Type of Treatment: Thermal

Country: France

Institution/Contact:

Michel Lavanchy
Vicarb S.A.
24, Avenue Marcel-Cachin
38400 Saint-Martin-D'Heres,
France
Tel.: 76-25-2045

Pierre Boutan
Director, Science &
Technical Liason
Rhone-Poulenc
52 Vanderbilt Avenue
New York, NY 10017
Tel.: (212) 883-1260

Function: Thermal destruction process for solid, liquid, or gaseous chlorinated organic solvents containing a chlorine content of up to 80%, including PCBs (pyralenes, arochlors, askarels, PCDD, PCDF, etc.), chlorophenols, pesticides, inorganic salts, contaminated soils, and wastes/sludges with metal contents up to 7 percent (for most metals except polyvalent types such as Cr^{+6} where lower limits on concentrations may apply).

Description: The VCR process consists of a burner, quench system, HCl recovery system, steam recovery system, and a gas neutralization system. These components are discussed below.

- Burner--The atomization and combustion performed in this burner allows a local temperature of combustion close to 1,600°C in a furnace having an average temperature of 1,300°C. The burner does not require pressure on the fluids and uses air at 0.3 to 0.5 bar for the atomization,
- Quench--Made of graphite of an absolute reliability, the quencher cools combustion gases from 1,300°C to 60 to 80°C instantaneously, thus freezing the Deacon equilibrium.
  Advantages: limits corrosion, and maintenance.
- Recovery of HCl Solution--An isothermal absorption of HCl contained in the gases is carried out. The concentration of the HCl produced depends on the acid content of the gases at the quencher outlet. Generally, a 33% HCl solution is produced that can be either commercialized or distilled.

Description (cont.):

- Steam Recovery--3/4 of the residual combustion heat can be recovered to produce steam at 12 to 13 bars. A boiler is installed between the furnace and the quencher, with a combusting exhaust temperature of 300°C.

- Gas Neutralization--The low HCl and chlorine concentrations remaining in the gases after absorption must be neutralized before discharge to the atmosphere. Neutralization is performed by means of soda, according to a specific process in which soda consumption is minimized, although a large quantity of CO_2 is present. The hypochlorites thus produced are decomposed in the liquid draining of this neutralization and the gases thus formed ($CO_2 + Cl_2$) are recycled in the furnace.

- Solid Residues--When solid residues must be destroyed, a rotary kiln can be provided before the traditional furnace for liquid, which is then used as a post-combustion chamber. The retention time in the rotary kiln is controlled to ensure complete destruction of the chlorinated residues.

Performance: The process has achieved:

- Destruction efficiency according to standards (e.g., 99.9999%);

- Contents in the fumes lower than existing norms:

  - $HCl + Cl_2$ 50 ppm
  - NOx 200 ppm
  - PCDD - PCDF present detection limit

- Working factor: above 0.9 (higher than 8,000 hours/yr);

Limitations: None noted.

INTERNATIONAL TECHNOLOGY FACT SHEET (continued)

Economics: For 1 ton of average formula residues-C_2H_2 $Cl_{1.8}$:

- Electricity (kWh): 150 - 200
- Process water (m^3/h): 1.6
- Cooling water (m^3/h): 180 at 14°C
- 100% soda (kg/h): 9.2
- Gas (methane) (kg/h) 32

Production: 16 bars steam (kg/h): 4,400
33% HCl (kg/h): 2,300

Capital costs for a 2 ton/hr unit are on the order of $5 million.

Status: The VCR process has been developed for over 15 years and ten units have been installed throughout the world as of January 1986: France (3), Spain (1), Morocco (1), USSR (4), and USA (1 by Borden in Geismar, LA in 1982).

Recommendations: Update status.

Reference: Vicarb S.A., Combustion of chlorinated residues. (Pamphlet) January 22, 1986.

INTERNATIONAL TECHNOLOGY FACT SHEET

Process: Petrifix® Stabilization Process at the Gerland Dump Site: Noyelles sous Bellonne, France

Type of Treatment: Physical/Chemical

Country: France

Institution/Contact: Georges Millieret
Tech. Manager, TREDI Corp.
A-3. AO. Georges Pomjiolou,
Lyon, France
Tel.: 72-33-04-17, and

ANRED, Ministry of Environment, France

Function: Chemical neutralization and stabilization of oil refinery wastes.

Description: As noted in the March 1987 NATO/CCMS Report, site clean-up at the Gerland Dump Site proceeded as follows:

- Neutralization/Stabilization
    - Pumping of cold or, if necessary, electrically-heated acid tars;
    - Controlled mixing of pumped tars with adjusted quantities of preselected chemicals (exact chemicals not mentioned in paper); and
    - Discharge of the treated materials in a previously emptied lagoon in which a limestone layer had been put above the polymerized bottom.
- At the end of the clean-up operation, covering stabilized dump with a vegetative soil cover.

Tredi Corp. (owner of the PETRIFIX trademark was responsible for operations on behalf of the Gerland Company under the control of local authorities and with the assistance of ANRED hazardous dump sites' team.

Performance: No data were available.

Limitations: Clean-up interrupted due to corrosion of electric heating rods. Pumping no longer possible due to an increase in viscosity, as well as presence of very heterogenous solid wastes (garbage, empty drums) mixed with the remaining tars. Treatment process resumed with waste excavation by mechanical shovel and mechanical mixing with added chemicals.

Economics: Cost of clean-up: 4,796,000 FF including 118,000 FF for incineration tests (incineration option proved too costly).

Status: Operation completed in September 1983. Grass has been grown on the vegetative soil and the site sold to a farmer to be used for cattle breeding.

Recommendations: Update status through NATO/CCMS project.

Reference: NATO/CCMS Pilot Study; Demonstration of Remedial Action Technologies for Contaminated Land and Groundwater. 1st International Workshop, Karlsruhe, Federal Republic of Germany. 16-20 March 1987.

INTERNATIONAL TECHNOLOGY FACT SHEET

Process: The Neostar Process: High-temperature/high-pressure Steam Cracking of PCBs

Type of Treatment: Thermal

Country: France

Institution/Contact: Centre d'Etudes et Researches du Charbonnages de France
Vernevil, France
Project Leader: Marc Kazmierczak

Function: This process destroys polychlorinated biphenyls using high-pressure/high-temperature steam without producing hazardous byproducts of furans and dioxins.

Description: In the Neostar process, steam for cracking PCBs is produced at 2,900°C by reacting hydrogen and oxygen over a burner in a refractory-lined furnace. The steam is fed to the reactor which operates under atmospheric pressure at 1,500°C. Preheated liquid PCBs are injected into the reactor. The process breaks down PCBs to byproducts of chlorine and a mixed stream of methane, ethane, and other substances that can be disposed of easily. The process does not form dioxins and furans because the PCB molecules are broken up using high-temperature, high-pressure steam without introducing oxygen into the reaction chamber.

In a newly constructed pilot plant, the cracked products are separated, with the chlorine neutralized in caustic soda and the hydrocarbon stream recycled to feed the burner. In a commercial unit, the chlorine could be used to produce hydrochloric acid.

Performance: No performance data are available.

Limitations: None listed.

Economics: Kazmierczak estimates processing costs at \$2/kg, a price competitive with incineration.

Status: Now at pilot plant status.

Recommendations: Progress should be monitored.

Reference: Kazmierczak, Marc. "Steam Cracks PCBs" (News Item), Engineering News Record, 8 January 1987.

INTERNATIONAL TECHNOLOGY FACT SHEET

Process: Cationic Metals Recovery from Effluent Waste Streams

Type of Treatment: Physical

Country: France

Institution/Contact: Proserpol Engineering
Bois d'Arcy, France

Function: A technique to remove metals more efficiently.

Description: A new continuous process is more efficient and consumes less iron than existing batch metal-recovery methods. Key to the process is a vibrating reaction vessel. In the process, the effluent stream passes into a 30-L vibrating vessel. Iron scrap particles (0.25 to 0.5 in.) are continually added. The constant vibration accelerates the electrochemical displacement, by the iron, of the copper and precious metals are carried out of the vibrating vessel by the solution. The entrained iron scraps are screened from solution, then the remaining copper and precious metal salts are separated in an agitated tank and filter press.

Performance: 99% of the copper, gold, silver and platinum from the effluent stream is recovered in a very short residence time (2 minutes) as compared with several hours in other technologies.

Limitations: None available.

Economics: No data available.

Status: Process is new, but status is unknown.

Recommendations: No further action recommended; limited value to Superfund site remediation.

Reference: Chemical Engineering (Int. Ed.) 11 May 1987, 94 (7), 9 (News Item).

INTERNATIONAL TECHNOLOGY FACT SHEET

Process: Actimag Magnetic Separation

Type of Treatment: Physical/Chemical

Country: France

Institution/Contact: Actimag, France/Technique used by Thompson CSF
Tel.: 010-33-50-39-33

Function: To enhance extraction of toxic metals from solution.

Description: The use of magnets to agitate a bed of iron granules has been applied to extracting valuable or toxic metals from solution. The technique is being used by Thomson CSF to extract highly toxic byproducts of chromium plating, and may also be used to recover copper and other metals from chemical solutions. Actimag's process is designed to enable safe iron to be substituted for chromium in the solution.

In contrast to conventional contact precipitation techniques, the solution is passed through moving iron granules, not static ones.

Performance: The Thomson CSF plant processes 10 m^3 of chromium effluent an hour.

Limitations: No data available.

Economics: The electromagnets that vibrate the iron granules reportedly consume 5 kw of electricity.

Status: Pilot-scale.

Recommendations: No further study recommended. Has limited application to Superfund wastes.

Reference: Engineer, "Magnetic Bed Aids Metal Extraction." 264 (6839-6840), 85. April 23-30, 1987.

INTERNATIONAL TECHNOLOGY FACT SHEET

Process: Organic Carbon Conversion in a High Compacting Multiphasic Reactor (HCMR)

Type of Treatment: Biological

Country: France

Institution/Contact: S. Elmaleh, S. Papaconstantinou, G.M. Rios, A. Grasmick
Laboratory Genie Procedes
Univ. Sciences Tech. Languedoc
34060 Montpellier, France

Function: An innovative bioreactor with potential use in aerobic biological wastewater treatment. It performs aeration and stirring.

Description: The high compacting multiphasic reactor (HCMR) is a three-phase spouted bed in which regular solid circulation is ensured by a special distributor. The oxygen transfer characteristics of the HCMR and its potential use in aerobic biological wastewater treatment were evaluated in the literature. The HCMR promotes tight three-phase contact even when the solid phase is difficult to fluidize. The oxygen transfer is intense with low energy requirements; the HCMR compares with the most efficient aeration system. Although biomass hold-up is relatively low because of the intensity of the drag forces, the HCMR was reported as one of the most intensive reactors for organic carbon conversion with low energy requirements and low sludge production.

The HCMR is an alternative to the fluidized bed, the upflow sludge blanket and activated sludge. It reportedly offers the best performance for intermediate influent concentrations (between 1 and 5 kg COD m^{-3}).

Performance: The HCMR can treat an influent at a loading rate of 24 kg COD m^{-3}/day with more than 80 percent conversion.

Limitations: Biomass holdup is lower than in a classical aerobic fluidized bed.

Economics: The energy requirement for the conversion of 1 kg COD is about 1 kw hour. Cost data for a full-scale reactor is not available.

Status: Developmental; bench-scale.

Recommendations: No further study recommended. Limited Superfund waste applications.

Reference: Elmaleh, Papaconstantinou, Rios, and Grasmick. "Organic Carbon Conversion in a Large-Particle Spouted Bed." The Chemical Engineering Journal, 34 (1987) B29-B34.

INTERNATIONAL TECHNOLOGY FACT SHEET

Title: An Active Denitrification Medium to Promote Anaerobic Biodegradation

Type of Treatment: Biological

Country: France

Institution/Contact: Bruno Cabane, Joel Vergnault
PCUK Products
Chimique Ugine Kuhlman, Paris

Function: An active denitrification support for anaerobic denitrification of effluents containing up to 10 g/L of nitric nitrogen.

Description: The support is produced by mixing denitrifying bacteria with organic carbon and calcium nitrate in an anaerobic environment. A central inactive carbonaceous nucleus is obtained by adding an unassimilable carbonaceous material to the denitrification medium comprised of the bacteria and calcium nitrate. A homogeneous, fluidized-bed or fixed-bed reactor is typically used.

Performance: The results of one experiment involving the denitrification support are shown in Table 1.

INTERNATIONAL TECHNOLOGY FACT SHEET (continued)

TABLE 1. RESULTS OF DENITRIFICATION SUPPORT

Influent nitric N (mg/L)	Dwell time (hours)	% Nitrogen purification
700	60	99.9
1,400	60	99.3
2,100	60	98.0
2,800	120	99.3
8,400	130	90.0

Limitations: Unknown.

Economics: Data not available.

Status: This is a patented technology, U.S. No. 4,318,988. Current use appears to be limited to bench-scale reactors.

Recommendations: No follow-up recommended. Limited application to site cleanup wastes.

Reference: Technical Insights Inc. New Methods for Degrading/Detoxifying Chemical Wastes. Emerging Technologies No. 18. International Standard Book No. 0-914993-16-X, Library of Congress No. 85-51133. 1986.

INTERNATIONAL TECHNOLOGY FACT SHEET

Title: Catalytic Hydrodehalogenation

Type of Treatment: Chemical

Country: Hungary

Institution/Contact: Mr. Antal Tungler
Hungarian Academy of Sciences
Research Group for Organic Chemical Technology
H-111 Budapest, Muegyetem rkp. 3
Hungary

Function: Dehalagenation of multi-chlorinated compounds.

Description: A new type of supported palladiam catalyst activates hydrodehalgenation. In other words, the catalyst removes the chlorine atoms and replaces them with hydrogen atoms. For example, tetra-and penta-chlorobenzene with supported paladium catalyst at atmospheric pressure and at temperatures of 120-140°C will react to form benzene and chlorobenzene.

Performance: Data not available.

INTERNATIONAL TECHNOLOGY FACT SHEET

Limitations: Information not available.

Economics: The high activity of the catalyst makes it possible to use a low amount of it, thus reducing costs.

Status: The catalyst is patented (USA: 4,361,500, Hungary: 177,860) as well as the technology (Hungary: 178,872) but was reported as being in the experimental lab stage.

Recommendations: This technology is not applicable to Superfund site remediation.

Reference: Máthé, T., Tungler, A. and J. Petro. "Active environment protection: hydrodehalogenation of multi-chlorinated compounds" Abstracts of the Hazardous Waste World Conference, October, 1987.

INTERNATIONAL TECHNOLOGY FACT SHEET

Title: Waste Elimination by Application of the Plasma Technique

Type of Treatment: Electrical

Country: Hungary

Institution/Contact: Mr. Otto Boday
Villamosipari Kutato Intézet
Bp. XV., Cservenka Miklos u. 86
Tel. 831-927

Function: Destruction of toxic wastes including highly halogenated hydrocarbons and heavy metals, while recovering energy and producing usable chemicals.

Description: The Electrical Industry Research Institute has been developing a process where wastes are brought into a plasma state, breaking down the chemical bonds. This occurs in the high oxygen content, high temperature atmosphere of the plasma reactor. The gases leave the reactor in the form of chlorine-, sulfur-, or metal-oxides. A cooler- and washer-separator system was developed especially for this system by the Ventilation Works and the Veszprém University of Chemistry (both in Hungary). By this device, a large portion of the heating energy used to decompose the wastes is recovered while reusable chemical materials are also produced.

In comparison to the Westinghouse plasma incinerator, the Hungarian model does not flare its outgases. The Hungarian plasma nozzle receives the wastes in vaporized form, not in the original liquid state used in the Westinghouse system. Unlike Westinghouse, the Hungarians claim to recycle some of the heat produced as well as produce reusable chemicals from the operation. A schematic of the system is shown in Figure 1.

Performance: The authors claim the non-reusable part of the wastes are "environment-friendly" ones. Data are not available.

INTERNATIONAL TECHNOLOGY FACT SHEET (continued)

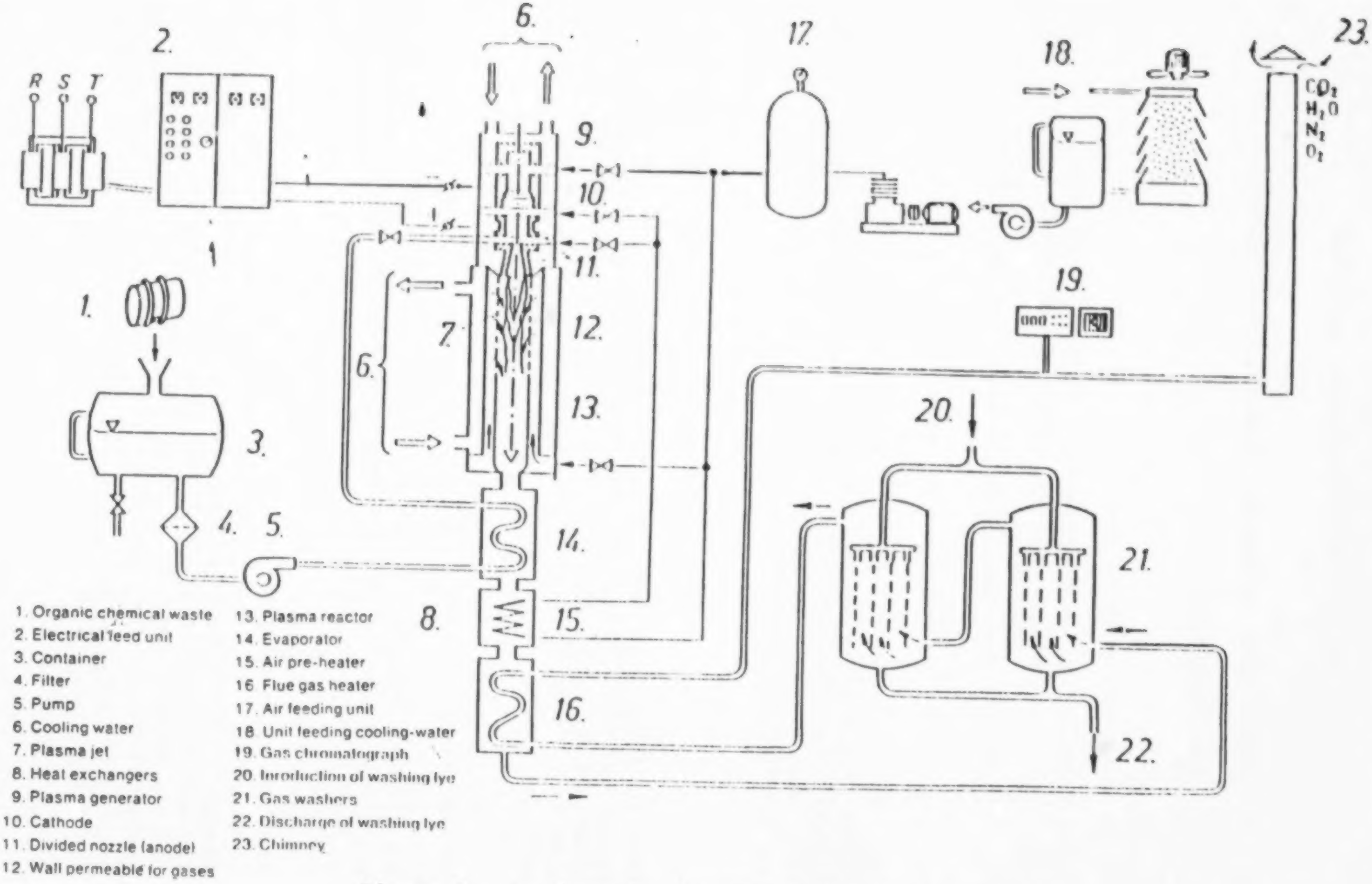
Limitations: Unknown.

Economics: Unknown.

Status: An "industrial size research plant" has been built using the plasma technology.

Recommendations: Monitor program.

Reference: Krajcsovics, Dr. F., Pócsy F., Emhő, Dr. L. and Dr. Zs. Puskás. "Making Harmless of Specially Hazardous Chemical Industry Wastes by Plasma Technology". Abstracts of The Hazardous Waste World Conference, October 1987.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CO_2
H_2O
N_2
O_2
1. Organic chemical waste
2. Electrical feed unit
3. Container
4. Filter
5. Pump
6. Cooling water
7. Plasma jet
8. Heat exchangers
9. Plasma generator
10. Cathode
11. Divided nozzle (anode)
12. Wall permeable for gases
13. Plasma reactor
14. Evaporator
15. Air pre-heater
16. Flue gas heater
17. Air feeding unit
18. Unit feeding cooling-water
19. Gas chromatograph
20. Introduction of washing lye
21. Gas washers
22. Discharge of washing lye
23. Chimney

Figure 1. A schematic diagram of the plasma process.

INTERNATIONAL TECHNOLOGY FACT SHEET

Process: DDT Degradation by Bacteria from Activated Sludge

Type of Treatment: Biodegradation

Country: India

Institution/Contact: Surya Kanta Sharma, University of Delhi, New Delhi
K.U. Sadasivam, Indian Agricultural Research Inst., New Delhi
J.M. Dave, Nehru Univeristy, New Delhi

Function: Research to evaluate DDT degradation potential of activated sludge in a bench-scale reactor. Research is investigating isolated bacteria obtained from sludge liquors enriched with increasing amounts of DDT. This research may lead to application of these techniques in cleanup of DDT-contaminated sites.

Description: DDT-contaminated soil and cow dung was used to develop a mixed culture of micro-organisms. The micro-organisms were extracted and incubated with a synthetic sludge consisting of whole milk powder, glucose and tap water, in bench-scale hopper bottom tanks. The tanks were continuously mixed and aerated with increasing amounts of DDT (1 to 55 mg/L) added once daily. Following this period, the mixed liquor was allowed to settle with settled sludge, then siphoned out and analyzed for DDT and metabolites.

The mixed liquor was further enriched with DDT before isolating the bacteria. From 25 different bacterial strains, seven showing good growth in high concentrations of DDT were isolated from the liquor. The isolated bacterial culture was then incubated in an inorganic broth consisting of $Na_2\ HCO_4$, $KH_2\ PO_4$, $NH_4(SO_4)$, $MgSO_4$, $Ca(NO_2)$, yeast extract, and water. Two standard solutions of DDT (containing 5 mg/L and 20 mg/L of DDT) were added to the incubation flasks. After 6 weeks of incubation, under static culture conditions, the entire contents of the flasks were extracted and estimated for DDT and its metabolites. Based on morphological and biochemical characteristics, the isolated materials were identified as Pseudomonas sp., P. aeryginosa, Micrococus, B. pumilus, B. circulans, Bacillus sp, and Flavobacteriom sp.

Performance: Analysis of the contents of the flask containing the isolated bacterial culture and DDT showed almost complete removal of DDT with a negligible formation of non-polar pollutants (DDD or DDE). The biodegradation of organic pollutants, in general, was shown by 88.6 to 99.1% reduction in COD and BOD. Analysis of the reactor sludge extracted prior to the isolation of specific bacteria indicated higher levels of DDT, possibly due to the solubility of DDT in lipids and fats of the micro-organisms and milk. Flavobacteria and microiocous were found to be the most active degraders causing 60 to 69% of degradation of DDT, while P. aeruginosa and B. pumilus were least active (44% degradation).

The results of the experiment clearly show the presence of bacterial cultures in nature capable of degrading the DDT to less persistent compounds under suitable conditions. The amount of DDT degraded by bacteria was found to increase with the amount of DDT added to the system. The experiment shows that these bacteria utilize DDT as a carbon source.

Limitations: Limited to wastewater applications.

Economics: Not available.

Status: Experimental - laboratory conditions.

Recommendations: No further action recommended; this technology probably has limited value for superfund waste.

Reference: Sharma, Surya Kanta, et al. "DDT Degradation by Bacteria from Activated Sludge." Environment International, Vol. 13, pp. 183-190. 1987.

INTERNATIONAL TECHNOLOGY FACT SHEET

Process: Microbial Detoxification of Cyanide from Wastewater

Type of Treatment: Biological

Country: India

Institution/Contact: N. Shiuaraman and N.M. Parhad
National Environmental Engineering Research Inst.
Nehru Mayg, Nagpor 440020 (India)

Function: This research investigation established the biodegradation of alkali cyanide by specific microbial sludge developed in the laboratory, and determined the influence of heavy metals on this process. The feasibility of biological removal of cyanide from gold ore processing wastewater was also investigated.

Description: Studies were conducted to determine the biodegradation of cyanide by continuous feeding experiments. Microbial sludge was developed in an aeration unit with synthetic cyanide waste containing either peptone or domestic sewage as organic nutrients. The unit was also seeded with the previously isolated *Pseudomuras acidouorans*. The synthetic cyanide wastewater was composed of sodium bicarbonate, potassium dihydrogen orthophophate, magnesium sulfate, calcium chloride, ferric chloride, and distilled water. Heavy metals were incorporated into wastewater for separate tests to determine heavy metal influence on degradation. Gold ore processing wastewater was mixed with the sewage (in additional experiments) to determine industrial applicability of this process.

The cyanide-containing wastewater was fed into the aeration unit by an electrolytic feeding unit after the microbial sludge was developed to around 1,000 mg/L as a mixed liquor suspended solids (MLSS). The bench model mixed aeration system was operated at a hydraulic detention time of around 12 hours. Random measurements were taken to determine cyanide (influent and effluent) levels, metals, BOD and COD, as well as MLSS.

Performance: Cyanide loading with peptone and sewage worked out to be 0.131 and 0.130 g (CN-1g MLSS/day), respectively. Results indicated cyanide could be degraded by the microbial flora from both systems (peptone and sewage) with greater than a 99 percent reduction. With regards to heavy metals, it was determined that zinc up to 50 mg/L and cadmium up to 20 mg/L did not influence cyanide degradation. Copper, however, even at 5 mg/L affected effective cyanide removal. In addition, cyanide present in gold ore wastewater could be degraded, however, its removal to the extent desired (0.2 mg/L) was not achieved.

Limitations: The use of these techniques in the industrial setting where levels of heavy metals are unpredictable, may prove less effective than the laboratory test.

Economics: Not provided.

Status: Experimental.

Recommendations: No follow-up recommended. Limited Superfund waste applications.

Reference: U.S. EPA HWERL. Proceedings: International Conference on New Frontiers for Hazardous Waste Management. September 15-18, 1985. Pittsburg, PA. Co-sponsored by NUS. EPA-600/9-85/025. September 1985.

INTERNATIONAL TECHNOLOGY FACT SHEET

Process: Degradation of Polychlorinated Biphenyls by Microorganisms

Type of Treatment: Biodegradation

Country: Japan

Institution/Contact:
Osami Yagi & Ryuichi Sudo
Laboratory of Freshwater Environment
National Institute for Environmental Studies
Yatabe, Ibaraki-Ken, Japan

Function: PCB degradation.

Description: A bacterium which was able to decompose PCBs was isolated from soil. This strain was identified as Alcaligenes by morphological and physiological characteristics.

Performance: 500 ppm of PCB predominantly containing mono- and dichlorobiphenyl was significantly decomposed in 3 days by this organism. Eighty percent of the 100 ppm of PCB, predominantly tri- and dichlorobiphenyl was degraded after 6 days' cultivation by the addition of meat extract and peptone.

Limitations: Not available.

Economics: Data not available.

Status: Laboratory experiment.

Recommendations: Process status requires further updating and further tests are needed before this technology can be assessed.

Reference: Yagi, O., and R. Sudo. Degradation of Polychlorinated Biphenyls by Microorganisms. Laboratory of Freshwater Environment, National Institute for Environment Studies, Japan. Undated.

INTERNATIONAL TECHNOLOGY FACT SHEET

Process: Fujibeton Encapsulation Process

Type of Treatment: Physical

Country: Japan

Institution/Contact:
U.S. Marketing Agent is: New Materials Tech. Corp.,
Jeffrey P. Newton, President
8709 Arthur Circle
Wichita, Kansas 67207
316-683-8896
Developed by Dr. Jiro Fujimasu
Fujimasu Synthetic Chemical Laboratories, Tokyo

Function: This process involves the encapsulation of wastes using a silicate material which has an improved cross-linking ability and which increases the number and types of bonding sites around a silicate macromolecule.

Description: For chlorinated hydrocarbons contained in still bottoms, a semisolid or sludge which is assumed to have a specific gravity of 1.1, an absorbent such as fly ash would first be mixed with the waste. This mixture would then be mixed with Fujibeton's proprietary silicate material in a ratio of 1 part by weight of still bottom to 0.20 part Fujibeton. After cure, it would be disposed of as nonhazardous fill.

Alkaline electroplating wastes, in solution, with an assumed specific gravity of 1.0, would also be mixed with fly ash in equal parts by weight. This mixture would be treated with Fujibeton, in the same ratio of 1 to 0.2, and disposed of after cure as fill. In the case of acidic electroplating wastes, specific gravity 1.0, neutralization to pH 8.5 would be needed and that would require 0.27 lb of lime/lb of solution. In the case of chlor-alkali cell wastes, a specific gravity 1.1 would be required before the Fujibeton treatment.

Fujibeton is supplied in three different products: Fujibeton PC, a sludge solidifier that immobilizes hazardous constituents of sludge; Fujibeton B, a soil cement that strengthens the soils used in landfill liner and cover systems and reduces the permeability of those soils; and Thomasbeton, a high-strength cement that resists corrosion and high temperatures. It is suggested for use in structural and lining systems for waste treatment tanks.

TABLE 1. EFFECT OF FUJIBETON ON ELECTROPLATING SLUDGES

EPA Toxicity Tests of Electroplating Sludge

	Sample 1	Sample 1	Sample 2	Sample 2
Toxic component	Untreated concentration (ppm)	Treated leachable (ppm)	Untreated concentration (ppm)	Treated leachable (ppm)
Cadium	4,700.00	0.06	3,200.00	0.03
Chromium	310.00	0.30	210.00	0.24
Copper	9,900.00	0.34	5,700.00	0.71
Zinc	24,000.00	0.88	15,000.00	0.32
Nickel	190.00	0.16	140.00	0.13
Silver	4.3	0.036	3.5	0.030
Arsenic	11.00	<0.025	12.00	<0.025
Barium	47.00	0.25	101.00	0.34
Beryllium	0.78	<0.0002	0.88	<0.002
Mercury	<0.1	<0.0002	<0.1	<0.0002
Lead	1,700.00	0.52	1,200.00	0.37
Selenium	<5.0	<0.05	<5.0	<0.05

Tests were run 3 days after treatment.

Performance: Data presented indicate that for electroplating sludge, the levels of toxic compounds before and after were significantly reduced. Data were also supplied on sludges contaminated with PCB, one with 1800 ppm (0.069 ppm after treatment) and 9200 ppm (reduced to 0.337 ppm, 3 days after treatment). On a sludge with 2015 ppm chromium, the total chromium for nine extractions yielded 18.02 ppm. See also Table 1.

Limitations: None reported.

Economics: For the still bottoms, material cost estimates are 5¢/lb of still bottoms or 45¢/gal. For alkaline electroplating wastes, material costs are 5¢/gal. For acidic electroplating wastes, material costs are 7.5¢/lb of waste or $6.75/gal. For the chlor-alkali cell wastes, 4.7¢/lb of sludge or 45¢/gal. Costs were reported in 1986.

Status: The technology seems to be used extensively in Japan, based on the fact that 11 plants in Japan currently produce Fujibeton products. This process has been leased/sold to New Materials Technology Corp. of Wichita, Kansas, which has exclusive U.S. rights to the process.

Recommendations: Update on status within United States.

Reference: Technical Insights. New Methods for Degrading/Detoxifying Chemical Wastes. Emerging Technologies No. 18. International Standard Book No. 0-914993-16-X, Library of Congress No. 85-51133. 1986.

INTERNATIONAL TECHNOLOGY FACT SHEET

Process: Electrolytic Decomposition of Iron-Cyanide Complexes

Type of Treatment: Chemical

Country: Japan

Institution/Contact: Katsuhiro Okubo
Tokyo, Japan

Function: The process is a practical electrolytic method of decomposing iron-cyanide complex solutions.

Description: Iron-cyanide complexes, such as potassium ferricyanide or ferrocyanide, are troublesome and toxic ingredients of the wastes from such operations as a carburizing process for iron, plating or printing processes, and photo processing. They are relatively stable and not easily dissociated in an aqueous solution. The addition of strong oxidizing agents does not decompose such complexes unless a high temperature is used. Decomposition by electrolysis has not been practical because of its low efficiency. However, the Japanese method reportedly represents a practical electrolytic method, achieved by adjusting the specific conductivity of the electrolyte to not more than 30 mu/cm.

The apparatus used is shown in Figure 1. The Anode is constructed of electrolytic graphite, 31 mm in diameter. Part of it is coated with epoxy resin. The cathode is a titanium net. Anode and cathode are arranged in the electrolytic cell, about 8 to 9 mm apart. The cell's volume is about 100 cm^3. About 125 mL of electrolyte, adjusted beforehand to a predetermined temperature in a constant temperature bath, is fed through a roller pump into the bottom of the cylindrical glass electrolytic cell at a flow rate of 80 mL/min for continuous circulation in an overflow system. A voltage is applied between the electrodes to control anodic current density, the quantity of electricity and the bath temperature.

Products of the electrolysis are cyanic acid and an iron hydroxide precipitate. Gas produced at the electrode is discharged through the condenser to minimize evaporation of water and loss of electrolyte. Figure 2 shows the results of operation at specific conductivities of electrolyte of 5, 10, 15, 20, and 30 mu/cm at 25°C with addition of a convenient quantity of sodium carbonate. An aqueous solution of potassium ferricyanide containing 100 mg/L of iron and 280 mg/L of cyanide was used as electrolyte. pH ranged from 11.0 to 11.4.

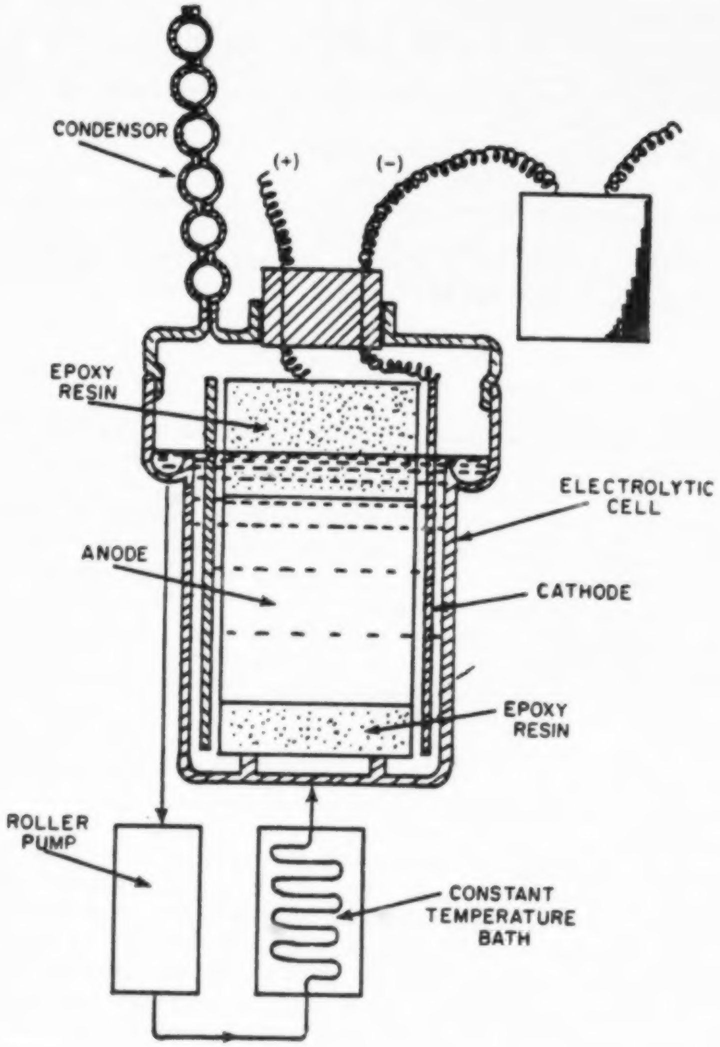

CONDENSOR
(+)
(-)
EPOXY RESIN
ELECTROLYTIC CELL
ANODE
CATHODE
EPOXY RESIN
ROLLER PUMP
CONSTANT TEMPERATURE BATH

Figure 1. Apparatus used in electrolytic method of decomposing iron-cyanide complexes.

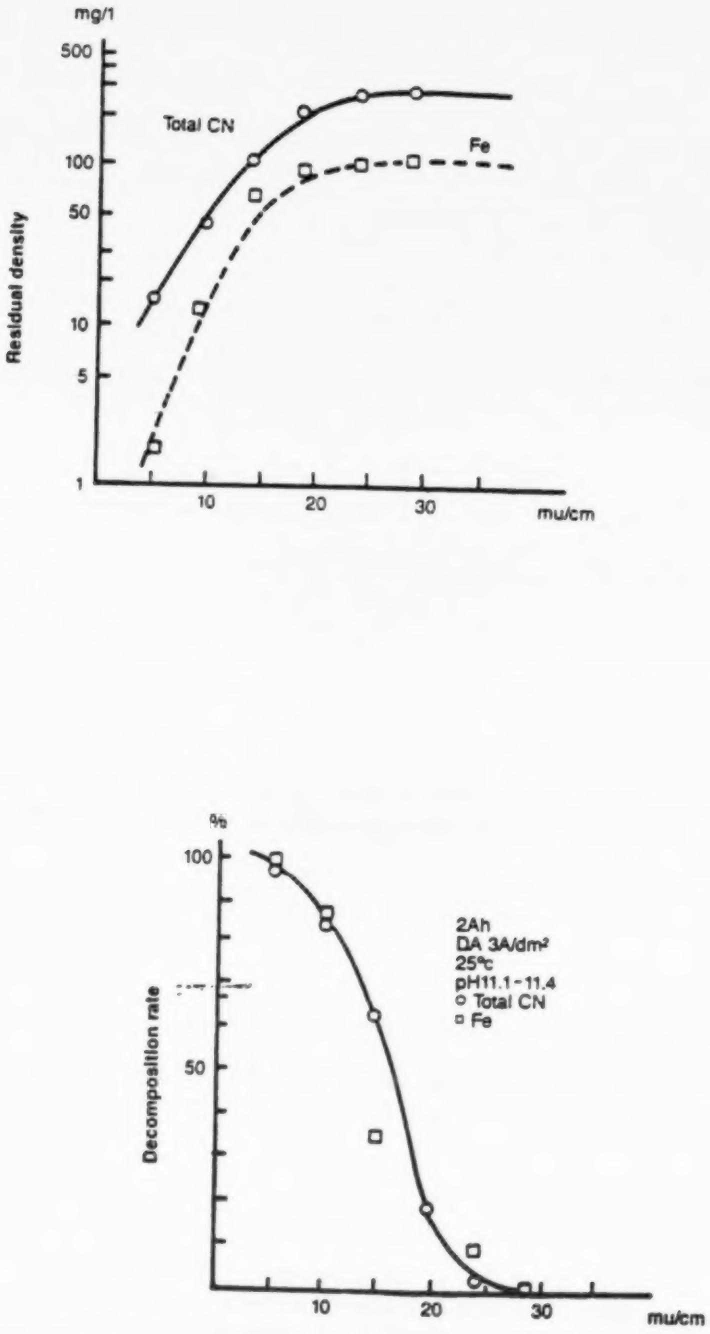


Figure 2. Results of electrolysis process for decomposing iron-cyanide complex at several specific conductivities.

INTERNATIONAL TECHNOLOGY FACT SHEET (continued)

Performance: See Figure 2 for performance data. The results show significant decomposition of the complexes.

Limitations: Not available.

Economics: No cost data are available.

Status: The method is described in U.S. Patent 4,319,968 to Atsuyuki Ueno and Junichiro Yokota of Tokyo and assigned to Katsuhiro Okubo, also of Tokyo.

Recommendations: No further action recommended. Limited applicability to Superfund sites.

Reference: Technical Insights. New Methods for Degrading/Detoxifying Chemical Wastes. Emerging Technologies No. 18. International Standard Book No. 0-914993-16-X, Library of Congress No. 85-51133. 1986.

INTERNATIONAL TECHNOLOGY FACT SHEET

Process: Biological Treatment of Phosphorous Compounds

Type of Treatment: Biological

Country: Japan

Institution/Contact: Shigezo Udaka and Makoto Shoda
Nagoya, Japan

Function: This process uses microorganisms to remove phosphorous from wastewater or ground water.

Description: The method consists of culturing any of several microorganisms that are capable of accumulating organic and inorganic phosphorus in water containing such compounds. The microorganisms are introduced to the contaminated water media, and are removed once they have accumulated the phosphorus compounds. The microorganisms are capable of accumulating and containing considerable quantities of phosphorus, releasing only very small amounts. Cultivation is preferably done under aerobic conditions, with pH between 6 and 8, and temperature between 25° and 40°C. Addition of other high BOD waters containing organic carbon or nitrogen or both, increases the efficiency of the process.

The microorganisms named in the patent are shown in Table 1, along with experimental data on phosphorus accumulation for each microorganism. For comparison purposes, similar data are given at the end of the Table on microorganisms that are not phosphorus accumulators.

Performance: See Table 1.

TABLE 1. EXPERIMENTAL RESULTS IN REMOVING PHOSPHORUS COMPOUNDS FROM WATER

STRAIN	Experimental Results		
	Concentration of Phosphorus in Supernatant ppm by wt	Dry cell Weight mg/l	Phosphorus Content in Cell g/g -- dry cell wt
Arthrobacter globiformis ATCC 8010	0.22	550	0.19
Arthrobacter simplex ATCC 15799	0.31	520	0.18
Micrococcus luteus ATCC 398	0.30	530	0.20
Micrococcus varians ATCC 399	0.29	540	0.20
Nocardia erythropolis ATCC 4277	0.42	580	0.18
Nocardia restrictus ATCC 14887	0.37	600	0.18
Cellulomonas uda ATCC 491	0.58	560	0.16
Cellulomonas biazotea ATCC 486	0.59	550	0.17
Oerskovia turbata ATCC 25835	0.63	540	0.18
Oerskovia xanthineolytica ATCC 27402	0.65	420	0.17
Corynebacterium bovis ATCC 7715	1.0	750	0.20
Corynebacterium aquaticum ATCC 14665	1.2	820	0.16
Brevibacterium linens ATCC 9175	3.0	480	0.15
Brevibacterium imperiale ATCC 8365	3.5	460	0.15
Kurthia zopfill ATCC 6900	6.7	720	0.13
COMPARISON			
Achromobacter lacticum CCM 69	80.0	504	0.04
Aerobacter aerogenes ATCC 7256	60.0	691	0.05
Flavobacterium heparinum ATCC 13125	75.0	440	0.06

Limitations: Not available.

Economics: No cost data are available.

Status: Udaka and Shoda were awarded U.S. Patent 4,220,527 for this process (assigned to the President of Nagoya University, Aichi, Japan).

Recommendations: Not applicable to Superfund wastes. No further action recommended.

Reference: Technical Insights. New Methods for Degrading/Detoxifying Chemical Wastes. Emerging Technologies No. 18. International Standard Book No. 0-914993-16-X, Library of Congress No. 85-51133. 1986.

INTERNATIONAL TECHNOLOGY FACT SHEET

Process: HWT Chemical Fixation Technology

Type of Treatment: Physical/Chemical

Country: Japan

Institution/Contact: U.S. Contact: International Waste Technologies
807 North Waco, Suite 31
Wichita, Kansas 67203
Tel.: (316) 262-1338 or (316) 683-8986

Function: International Waste Technologies (IWT) markets an advanced chemical fixation technology based on chemical mechanisms which "tie-up" or bond inorganic and organic toxic wastes in a variety of modalities. A significant percentage of the pollutant is chemically altered by the HWT treatment compounds. HWT Chemical Fixation Technology was originally developed in Japan.

Description: The process consists of a two-phased reaction in which the toxic elements and compounds are complexed first in a fast-acting reaction and permanently complexed further in the building of macromolecules which continue to generate over a long period of time.

The Phase 1 part of the chemical fixation or detoxification reaction can be described in terms of generating irreversible colloidal structures and ion exchanges with toxic metals and organics by special intercalation compounds. In a high percentage of reactions with halogenated hydrocarbons, a bimolecular displacement or substitution occurs as the first step in the linking mechanism to the Phase 2 macromolecules.

Phase 2, the generation of the macromolecule framework, is also a relative irreversible colloid synthesis, however, this is a slower moving reaction going from solid, to gel, to crystalline, three-dimensional, inorganic polymer. Of particular importance in the bonding of hazardous elements and compounds is the development in the Phase 2 part of the chemical reaction of the sulpho-ferri-aluminate hydrates. The bonding characteristics and durability of structure are varied to suit a particular waste situation and desired leaching standards by varying the composition of the HWT treatment compound.

Performance: Recent test results presented indicate that the process significantly reduces the leachability and concentration of the toxic compounds in the solid. Leach values for PCB using the EP Toxicity test were in the low ppb range, and the concentrations of PCB were reduced by greater than 50 percent in each case presented. Other test results indicate favorable results on other compounds as well.

Limitations: None listed, but mixing of the solidifier with soils in situ may create some problems.

Economics: No information available.

Status: This technology is scheduled for demonstration under EPA's SITE program.

Recommendations: Update status. Monitor results of U.S. EPA SITE study.

References: International Waste Technologies. "Presentation of the HWT Chemical Fixation Technology and Japanese In-Place Treatment Equipment." Undated.

McCoy and Associates, Inc. "New Technology Available for In-Situ Soil Treatment." The Hazardous Waste Consultant, Vol. 5, Issue 1. January/February 1987.

INTERNATIONAL TECHNOLOGY FACT SHEET

Process: Removal of Arsenic by Precipitation and Sedimentation

Type of Treatment: Physical/Chemical

Country: Japan

Institution/Contact: H. Kawashima, D.M. Misic, M. Suzuki
Institute of Industrial Science,
University of Tokyo
Tokyo, Japan

Function: Treatment of wastewater containing arsenic at concentrations of 2 to 3 ppm with a pH of 7.5 to 8.5, produced in a geothermal power generating plant.

Description: Wastewater and steam from the power plant initially enter a separator where steam is directed to the turbines and water enters a holding tank. A portion of the wastewater is then recycled to the underground well while the rest is pumped to a reactor where 150 m^3/hr of water are treated. Wastewater in the reactor is mixed with 3.9 L/h of 70% H_2SO_4, 14.9 L/hr NaOCl (7% Cl_2), 10 L/hr $FeCl_2$ (13% Fe). Water is then pumped to a mixing tank where NaOH (22%) is added, which raises the pH from 3-4 to 4-4.5. Slurry from the mixing tank enters a filter press where solids are separated out and taken by conveyor belt to a holding tank for final disposal. Depending on the concentration of arsenic in the filtrate, the filtrate may be recycled to the beginning of the treatment process or treated with NaOH (22%) to raise the pH, and released to the environment.

Chemical reactions involved in process are:

$$AsO^{3-} + NaClO \rightarrow AsO^{3-} + NaCl$$

$$AsO_4^{3-} + Fe^{3+} \rightarrow FeAsO_4$$

Performance: Arsenic concentration in treated water are reported to be generally below 0.05 ppm.

INTERNATIONAL TECHNOLOGY FACT SHEET (continued)

Limitations: No limitations are noted.

Economics: Cost for this treatment process is approximately Y150/m^3; in U.S. currency \$0.60/m^3.

Status: This treatment process is presently used by the:

Kyusha Electric Company
Ohdake, Hachiogahasa Plant
Ohita Prefecture, Kyusha

Recommendations: Limited Superfund applications. No further action recommended.

Reference: U.S. EPA HWERL. Proceedings: International Conference on New Frontiers for Hazardous Waste Management. September 15-18, 1985. Pittsburgh, PA. EPA-600/9-85/025. September 1985.

INTERNATIONAL TECHNOLOGY FACT SHEET

Process: Removal of Arsenic and Gallium by Precipitation

Type of Treatment: Chemical

Country: Japan

Institution/Contact: H. Kawashima, D.M. Misic., M. Suzuki
Institute of Industrial Science
University of Tokyo
Tokyo, Japan

Function: Treatment of wastewater containing arsenic and gallium from semiconductor production.

Description: Co-precipitation of arsenic and gallium from wastewater of a semiconductor plant is achieved through the addition of $Fe(OH)_3$, $FeCl_3$, and NH_4OH, at a pH of 7. Filtration is used to separate out the precipitate, which is then resuspended in water and NaOH, at a pH of 9 to 13, to redisolve the gallium. Arsenic remains in solid form which is filtered out and the sludge is prepared for final disposal.

Performance: Wastewater containing 10 ppm As and 10 ppm Ga and 100 ppm of Fe(III) was added and mixed with aqueous NH_4OH to raise the pH to 5.2. The co-precipitate, after separation, was resuspended in water and mixed with NaOH to raise the pH to 13. Arsenic concentration remaining in the solution containing gallium were below 0.5 ppm.

Limitations: Not noted.

Economics: Not provided.

Status: The process is in use by the Nippon Electric Company (NEC).

Recommendations: Limited Superfund applications. No further action recommended.

Reference: U.S. EPA HWERL. Proceedings: International Conference on New Frontiers for Hazardous Waste Management. September 15-18, 1985. Pittsburgh, PA. EPA-600/9-85/025. September 1985.

INTERNATIONAL TECHNOLOGY FACT SHEET

Process: Removal of Arsenic from Low pH Wastewaters

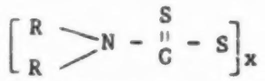
Type of Treatment: Chemical

Country: Japan

Institution/Contact: H. Kawashima, D.M. Misic., M. Suzuki
Institute of Industrial Science
University of Tokyo
Tokyo, Japan

Function: Treatment of wastewater containing arsenic from cadmium refining.

Description: Removal of arsenic in low pH wastewaters is achieved through the utilization of dialkyl thiocarbamate as a chelating agent. The alkyl group (R) can be methyl, ethyl, or n-butyl. For removal of arsenic from cadmium refining wastes, R_2 NCSS Na is used. The ratio of dialkyl thiocarbomate to arsenic ranges from 1 to 5. Wastewater is mixed with approximately one equivalent of dialky thiocarbamate at 400 rpm for 30 minutes at varying pH values. The compound makes the following metal complexes;


$\left[{}^{R}_{R}\!\!>N - \overset{S}{\overset{\|}{C}} - S \right]_x$. Me, which are precipitated. The precipitate is incinerated and the arsenic is recovered.

Performance: Best results are achieved at a pH of 1.1 at which more than 95% of arsenic is removed.

Limitations: The process is most efficient when the pH is between 1 and 2.5, and it is recommended only for pH below 3.

Economics: Not provided.

Status: The patent is available from the Nippon Mining Corporation.

Recommendations: May be applicable to the treatment of ground water contaminated with arsenic resulting from the discharge of wastewater from a cadmium refining plant, but no further action is recommended.

Reference: U.S. EPA HWERL. Proceedings: International Conference on New Frontiers for Hazardous Waste Management. September 15-18, 1985. Pittsburgh, PA. EPA-600/9-85/025. September 1985.

INTERNATIONAL TECHNOLOGY FACT SHEET

Process: Removal of Low Concentrations of Arsenic Using a Chelating Resin

Type of Treatment: Chemical

Country: Japan

Institution/Contact: H. Kawashima, D.M. Misic., M. Suzuki
Institute of Industrial Science
University of Tokyo
Tokyo, Japan

Function: Removal of arsenic from wastewaters having low concentrations (2 to 3 mg/L) of arsenic.

Description: A chelating resin containing $CH_2N - (R)\ CH_2\ [CH(OH)]_n\ CH_2OH$ moiety, where R is H or C_{1-5} alkyl and n is 1 to 6, is used to adsorb the arsenic out of solution.

Performance: The adsorption capacity of Amberlite IRA 743, one of the chelating resins, was 30 mg As^{3+} (per mL of resin).

Limitations: Not available.

Economics: Not provided.

Status: Patent held by Unitika Ltd., a manufacturer of synthetic fibers.

Recommendations: Limited Superfund applications. No further action recommended.

Reference: U.S. EPA HWERL. Proceedings: International Conference on New Frontiers for Hazardous Waste Management. September 15-18, 1985. Pittsburgh, PA. EPA-600/9-85/025. September 1985.

INTERNATIONAL TECHNOLOGY FACT SHEET

Process: Treatment of Arsenic-Containing Wastewaters with Titanium Compounds

Type of Treatment: Chemical

Country: Japan

Institution/Contact: H. Kawashima, D.M. Misic., M. Suzuki
Institute of Industrial Science
University of Tokyo
Tokyo, Japan

Function: Removal of arsenic from wastewaters that contain several metal ions.

Description: Wastewaters are treated with a titanium compound ($Ti[OCH(CH_3)_2]_4$) to form titanic acid, which forms a co-precipitate with arsenic. After co-precipitation and filtration, sludge containing arsenic can be disposed of in a landfill.

Performance: The process is most effective in the pH range 2-8. After co-precipitation and filtration, wastewater initially containing 97 mg/L of arsenic was found to contain 0.026 to 0.054 mg/L of arsenic.

Limitations: The only disadvantage is that the process requires 16 hours process time. Other titanium compounds may be substituted, such as $TiCl_4$ or $TiOSO_4$.

Economics: Not provided.

Status: Process developed by Mitsubishi Razor.

Recommendations: Limited Superfund application. No further action recommended.

Reference: U.S. EPA HWERL. Proceedings: International Conference on New Frontiers for Hazardous Waste Management. September 15-18, 1985. Pittsburgh, PA. EPA-600/9-85/025. September 1985.

INTERNATIONAL TECHNOLOGY FACT SHEET

Process: Adsorption of Arsenic by Red Mud

Type of Treatment: Phvsical/Chemical

Country: Japan

Institution/Contact: H. Kawashima, D.M. Misic., M. Suzuki
Institute of Industrial Science
University of Tokyo
Tokyo, Japan

Function: Adsorption of arsenic by red mud.

Description: Red mud, obtained from aluminum production, usually contains approximately 17 to 25% Al_2O_3, 25 to 50% Fe_2O_3, and 5 to 20% SiO_2. Al_2O_3 and Fe_2O_3 adsorb arsenic. Wastewater containing arsenic is shaken with red mud for 24 hours. The red mud is then shaken with 0.01 N sodium hydroxide for 24 hours, separated and reused.

Performance: In the pH range between 5 and 7, removal efficiency is over 99%.

INTERNATIONAL TECHNOLOGY FACT SHEET (continued)

Limitations: Not available.

Economics: A very low cost removal process.

Status: Developed by the Agency of Industrial Sciences and Technology, Japan.

Recommendations: Limited Superfund applications. No further action recommended.

Reference: U.S. EPA HWERL. Proceedings: International Conference on New Frontiers for Hazardous Waste Management. September 15-18, 1985. Pittsburgh, PA. EPA-600/9-85/025. September 1985.

INTERNATIONAL TECHNOLOGY FACT SHEET

Process: Plunging Water Jet System Using Inclined Short Nozzles for Aerobic Treatment of Wastewater

Type of Treatment: Biological

Country: Japan

Institution/Contact: A. Ohkawa, D. Kusabiraki, Y. Shiokawa, N. Sakai, and M. Fujii
Department of Chemical Engineering,
Niigata University, Niigata City 950-21, Japan

Function: Use of water jets for aeration for the removal of dissolved organic matter from wastewater.

Description: In the plunging water jet system, inclined, short nozzles spray jets of water forcing bubbles into the waste water. The gas entrainment rate and the bubble penetration depth change, depend on the jet velocity and the nozzle length. Other variables include the jet nozzle diameter, the jet length, and the jet angle.

It is attractive compared to conventional aeration systems because it does not need an air compressor, it is simple in construction and operation, and it is free of operational difficulties such as clogging in air diffusers.

Performance: When viewed from the removal ability of dissolved organic matter, the plunging jet aeration system was capable of treating a wastewater of considerable high loading without the rate of oxygen transfer becoming the biooxidation-rate-limiting factor.

The transfer efficiency at low jet velocities was not inferior to the ones of other types of existing aeration systems; i.e., the application of this jet aeration system to a high rate reactor for wastewater treatment is possible.

INTERNATIONAL TECHNOLOGY FACT SHEET (continued)

Limitations: There is an increased amount of fine suspended solids in the treated water caused by the shearing action between sludge flocs and pump blades. This action could also damage frail microorganisms that could be useful in biodegradation.

Economics: Data not available.

Status: Bench-scale apparatus, experimental.

Recommendations: Limited Superfund applications. No further action recommended.

Reference: Ohkawa, Akira et al. "Flow and Oxygen Transfer in a Plunging Water Jet System Using Inclined Short Nozzles and Performance Characteristics of its System in Aerobic Treatment of Wastewater." Biotechnology and Bioengineering. Vol. 28 (1986) 1845-1856.

INTERNATIONAL TECHNOLOGY FACT SHEET

Process: Mercury Roasting of Contaminated Soils

Type of Treatment: Thermal

Country: Japan

Institution/Contact:

Takashi Ikeguchi
Senior Research Scientist
Department of Sanitary Engineering
The Institute of Public Health
6-1, Shirokanedai 4 Chome,
Minato-Ku, Tokyo
108 Japan

Nomura Kosan Company
Itomulka, Hokkaido
(Owner of plant)

Function: Recovery of mercury from contaminated soils.

Description: A site in Arakawa-Ku, Tokyo is a former electrochemical industry site largely contaminated by mercury. Remedial technologies were selected according to the level of contamination as follows:

1. Thermal treatment (roasting) for heavily contaminated soil with percent order of mercury.
2. Underground containment after immobilization by addition of Na_2S, $Fe\ SO_4$, and colloidal sulfur for highly contaminated soil (above 10 mg/kg mercury).
3. Underground containment without pretreatment for moderately contaminated soil (2-10 mg/kg mercury).

In August 1984, containment was completed.

Initially, a small-scale onsite roasting plant (0.3 ton/day) was planned, but withdrawn due to opposition of the local residents and immature technology to control mercury vapors to under regulated levels. It was decided to transport this soil to the mercury recovery plant in the mountainous site of Hokkaido, about 1,000 km north of Tokyo.

Description (cont.):

This plant is equipped with a vertical, multistage roasting furnace called a Herreshoff furnace. The primary components of the plant are the roaster, a condenser to recover mercury, and flue gas cleaning devices. A flow diagram of this plant is shown in Figure 1. Mercury-containing waste or soil is roasted at temperatures of 600 to 800°C using heavy oil. Volatilized mercury is condensed on the inner wall of the condenser subsequent to dust removal. Trace amounts of mercury and acid gas components in the flue gas are removed by adsorption and neutralization. In 1987, the plant was expanded to recover mercury and other metals from used dry battery cells and other items.

Performance: Ground water wells just outside the containment pit have shown no ground water pollution so far. No data were available for the mercury roasting plant.

Limitations: Residues from the roasting furnace must be securely disposed of. At the Japanese plant, they are landfilled onsite.

Economics: The cost of soil roasting was 65,000 yen/ton and transportation costs (including packaging) were 16,000 yen/ton. The cost of underground containment and immobilization treatment is not yet available.

Status: This is a full-scale plant.

Recommendations: Follow-up on efficiency of mercury recovery and toxicity of residues.

Reference: Ikeguchi, Takashi. "Former Electrochemical Industry Site, Arakawa-Ku, Tokyo, Japan." 1st International Meeting at the NATO/CCMS Pilot Study Demonstration of Remedial Action Technologies for Contaminated Land and Ground Water. Washington, D.C. November 11-13, 1987.

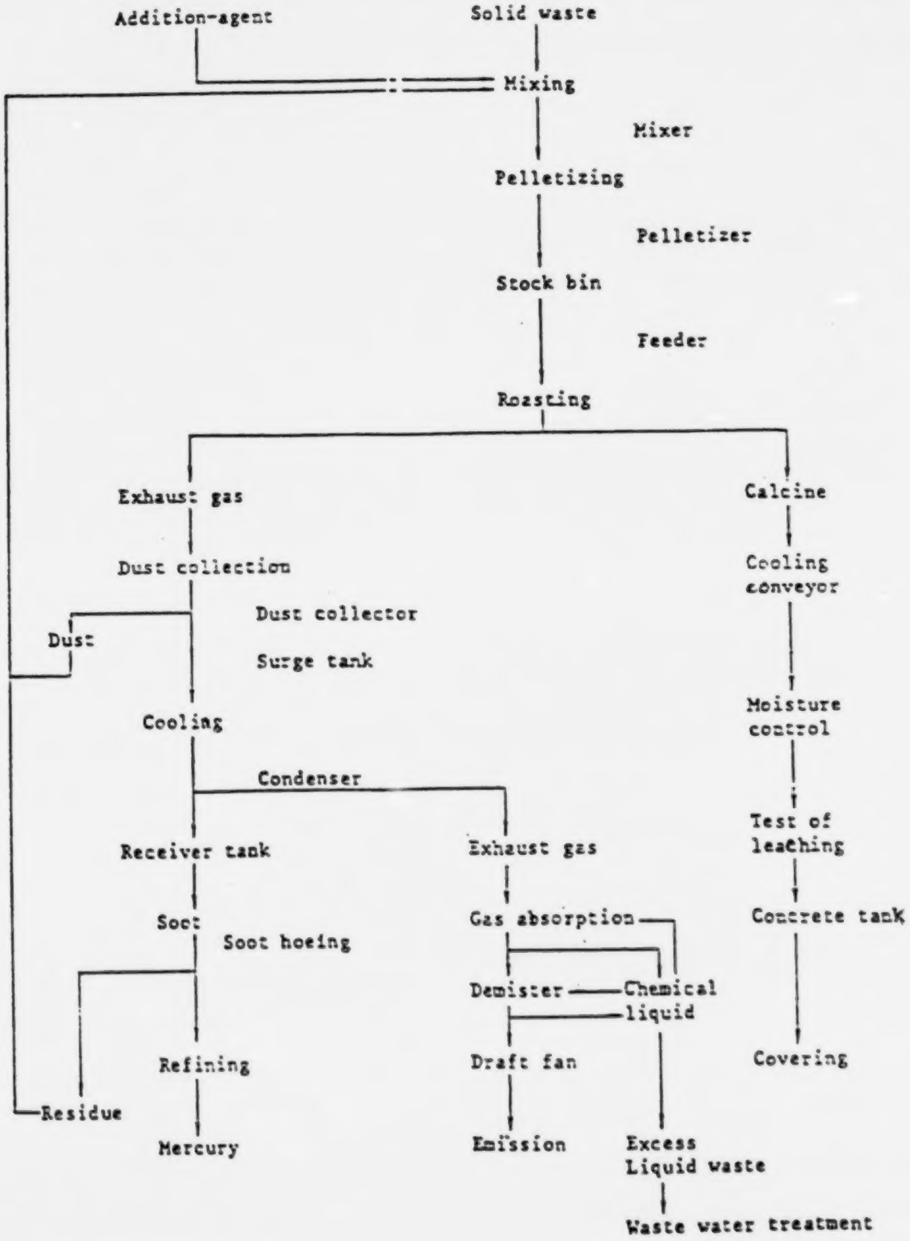

Addition-agent
Solid waste
Mixing
Mixer
Pelletizing
Pelletizer
Stock bin
Feeder
Roasting
Exhaust gas
Calcine
Dust collection
Cooling conveyor
Dust collector
Dust
Surge tank
Cooling
Moisture control
Condenser
Receiver tank
Exhaust gas
Test of leaching
Soot
Soot hoeing
Gas absorption
Concrete tank
Demister
Chemical liquid
Refining
Draft fan
Covering
Residue
Mercury
Emission
Excess Liquid waste
Waste water treatment

Figure 1. Flow diagram of mercury roasting.

INTERNATIONAL TECHNOLOGY FACT SHEET

Process: Extraction Techniques for Treatment of Soil in the Netherlands (Overview)

Type of Treatment: Physical

Country: The Netherlands

Institution/Contact: Ms. Ester R. Soczo
RIVM
P.O. Box 1
3720 BA Bilthoven, The Netherlands
Tel.: 030-743060

Function: Extraction of contaminants from soil as practiced in the Netherlands.

Description: This discussion is based on information provided in Attachment 5 (review of soil treatment technologies in the Netherlands) of the March 1987 NATO/CCMS Pilot Study Report. Specific details appear in Fact Sheets that follow.

The operational full-scale extraction plants in the Netherlands are indicated in Table 1.

TABLE 1. OPERATIONAL EXTRACTION PLANTS (MARCH 1987)

Name of Company	Capacity (ton/year)*	Costs Dfl/ton
BSN B.V.	25,000**	150-250
Heidemij Uitvoering B.V.	34,000	150-250
Heijmans Milieutechniek B.V.	14,000	150-250
HWZ Bodemsanering	27,000	150-250
Mosmans Mineraaltechniek B.V.	8,000	

*On the basis of 8 hr/day.
**The new plant of BSN is under construction.

Description (cont.): Some treatment results of Netherland plants are summarized in Table 2. The data show about 90 to 99 percent of contaminants like oil, cyanides, and PCAs can be removed from the soil. The cleaning efficiency for heavy metals varies between 70 and 95 percent.

The extraction technique is mainly suitable for treatment of contaminated sandy soils. However, the presence of small amounts of humus or clay in the sand does not cause any technical problems. Cleaning of other types of soil than sand will increase sludge generation, and will result in substantially higher costs.

TABLE 2. SOME TREATMENT RESULTS OF OPERATIONAL EXTRACTION PLANTS (MARCH 1987)

		Concentration mg/kg dry weight	
Type of soil	Contaminants	Initial	Final
Sand	Oil	500 - 10000	< 100
Sand, >10% loam	Mineral oil	1500 - 25000	80 - 150
Sand	CN	50 - 1000	8 - 25
Sand, 10% loam	CN	50 - 1000	10 - 20
Loamy sand	CN	250	7*
Sand, <2,5% humus	PCAs (16 EPA)	160 - 290	0.4 - 17
Sand, <10% peat	PCAs (16 EPA)	80 - 190	3 - 9
Sand	Cd	1 - 1750	1 - 2.5
	Pb	15 - 2050	42 - 75
Sand, >10% loam	Zn	150 - 1400	90 - 200
	Ni	50 - 900	40 - 75
Clayey sand	Pb	300 - 2000	50 - 150*

*Flotation technique.

Description (cont.):

Remarks

- Specifications of the types of oil and the types of cyanides were often not mentioned.
- Common measurements of PCAs are: the 16 PCAs according to EPA (USA).

After the application of an extraction technique, the soil structure is always changed with respect to humus-content and particle-size. The treated soil consists of sand with particle-sizes in a narrow band and can be re-used, for instance, for road construction or specific building materials.

Performance: See Table 2; some problem with residual concentrations is apparent.

Limitations: Residual concentrations appear to be a problem. Problems anticipated in removing contaminants from soils other than sand.

Economics: The costs of the treatment by means of extraction vary between Dfl 50-200/ton ($25-100/ton based on March 1987 equivalence), depending mainly on the quantity of small particles in the soil.

Status: Soil extraction techniques represent a major area of study in the Netherlands.

Recommendations: More data related to soil types and contaminants is needed. New approaches should be carefully followed as techniques offer definite advantages under certain conditions.

Reference: NATO/CCMS Pilot Study; Demonstration of Remedial Action Technologies for Contaminated Land and Ground Water. 1st International Workshop, S. Karlsruhe, Federal Republic of Germany. March 16-20, 1987.

INTERNATIONAL TECHNOLOGY FACT SHEET

Process: BSN Soil Extraction Plant

Type of Treatment: Physical

Country: The Netherlands

Institution/Contact: BSN-Bodemsanering Nederland
Daelderweg 15
Weert, The Netherlands
Tel.: (045)244850)

Function: Soil washing.

Description: The facility at Bodemsanering Nederland B.V. (BSN) has been in operation since 1983. It was originally developed to separate oil from sandy soil. The oil separation is based on a high pressure water jet curtain which physically separates the contaminants from the sand particles. A simplified process scheme is given in Figure 1. The process comprises the following steps:

1. Separation of coarse materials (+100 mm).
2. High pressure washing.
3. Separation of coarse sand by sieves and hydrocyclones (+63 um).
4. Separation of silt by sedimentation (30 to 63 um).
5. Separation of process water, oil, and fine mineral fraction (+30 um).
6. Dewatering of the treated soil.

Steps 4 and 5 may be enhanced by coagulants and flocculants. The process usually uses water without any additives. This fact offers the option of an additional microbiological treatment of the spent process water and/or the treated sand, as has been indicated in the process scheme. The process water will be often recirculated to the high pressure separator.

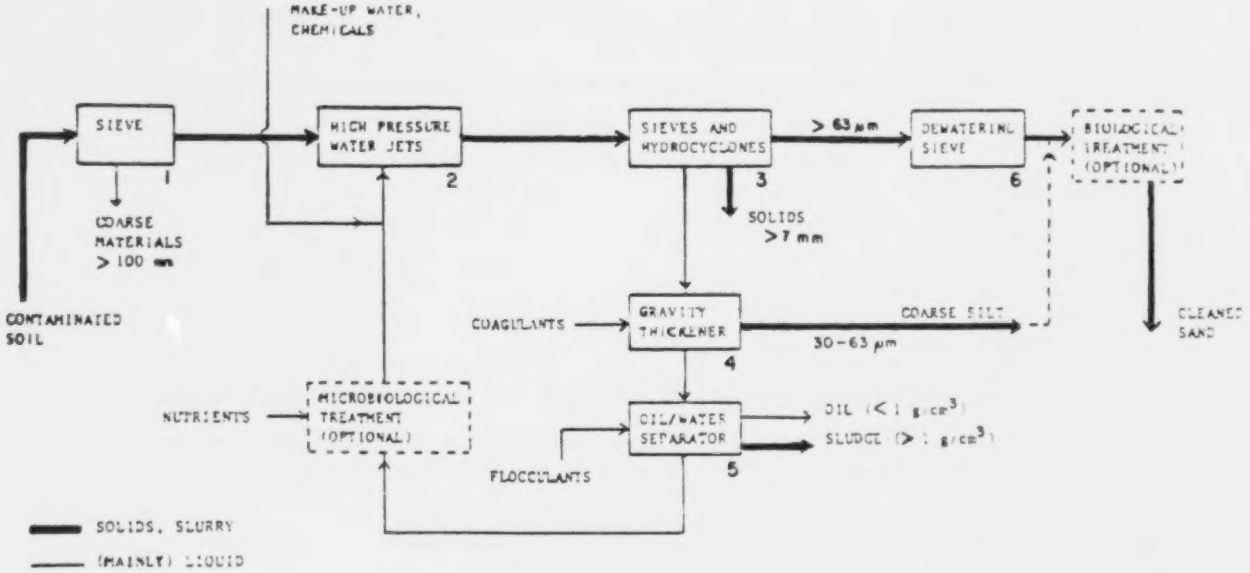

MAKE-UP WATER,
CHEMICALS
SIEVE
1
COARSE MATERIALS > 100 mm
CONTAMINATED SOIL
HIGH PRESSURE WATER JETS
2
SIEVES AND HYDROCYCLONES
3
> 63 μm
SOLIDS > 7 mm
DEWATERING SIEVE
6
BIOLOGICAL TREATMENT (OPTIONAL)
CLEANED SAND
COAGULANTS
GRAVITY THICKENER
4
COARSE SILT
30-63 μm
NUTRIENTS
MICROBIOLOGICAL TREATMENT (OPTIONAL)
OIL/WATER SEPARATOR
5
OIL (< 1 g/cm³)
SLUDGE (> 1 g/cm³)
FLOCCULANTS
SOLIDS, SLURRY
(MAINLY) LIQUID

Figure 1. Process scheme of the installation of Bodemsanering Nederland B.V.

Performance: BSN claims the following fields of application:

- All aliphatics and aromatics with low densities (floating on water);
- Contaminants that are largely adsorbed to those soil particles that will end up in the residual sludge (process step 5);
- Volatile contaminants, e.g., per- and trichloroethylene (these are stripped to the air when the soil is led through the high pressure washer);
- Some water-soluble and biodegradable hydrocarbons, provided the microbiological option is being chosen; and
- All types of soil with a maximum amount of residual sludge (< 63 um) of approximately 20 percent or approximately 2.5 ton/hr.

Some results obtained with this installation are given in Table 1.

TABLE 1. SOME PRACTICAL EXPERIENCES WITH THE TREATMENT INSTALLATION OF BSN

Contaminant	Initial concentration (mg/kg)	Concentration after treatment (mg/kg)	Removal efficiency (%)
Aromatics	240	45*	81
PNAs	295	15	95
Crude oil	79.000	2.300	97

*The concentration of aromatics was reduced to 10 mg/kg on account of microbiological activity 6 months after treatment.

Limitations: Applicable to only certain types of toxic substances.

Economics: 150 to 250 Dfl/tonne
Dfl 1 = $0.3 U.S. (June 1985)

Status: Operational since 1983. Originally developed to separate oil from sandy soil. Capacity: 20 ton/hr. Installation is easy to transport to a contaminated site.

Recommendations: Check status with TNO.

Reference: TNO - Assink, J.W. and W.J. van Den Brink. 1st International TNO/BMFT Conference on Contaminated Soil. November 11-15, 1985. Utrecht, The Netherlands. Published by Martinus Nijoff Publishers, Boston, MA. 1986.

INTERNATIONAL TECHNOLOGY FACT SHEET

Process: Heijmans Soil Extraction Plant

Type of Treatment: Physical/Chemical

Country: The Netherlands

Institution/Contact:
Mr. C. Jonker
Heijmans Milieutechniek
P.O. Box 2
5240 BB Rosmalen, The Netherlands
Tel.: 04192-89111

Function: Soil washing.

Description: The Heijmans Milieutechniek B.V. facility for extractive cleaning has been in operation since the Spring of 1985. A simplified process scheme is shown in Figure 1. The following steps may be distinguished:

1. Separation of coarse materials (10 mm).
2. Intensive mixing of soil and water in order to disperse all soil particles and to scour off the contaminants (scrubbing), in combination with a chemical oxidation (only in the case of cyanides, for detoxification).
3. Separation of coarse sand (60 um) by hydrocyclones.
4. Dewatering of the treated sand.
5. Separation of coarse, low-density materials, e.g., cokes and grass.
6. Separation of silt in a tiltable plate separator. Any free floating oil is skimmed off.
7. Coagulation and flocculation of the polluted extracting agent; followed by flotation of the formed flocs.

The cleaned extracting agents are generally recirculated to a great extent. It is possible to control the pH between approximately 3 and 12 in almost every apparatus of the plant.

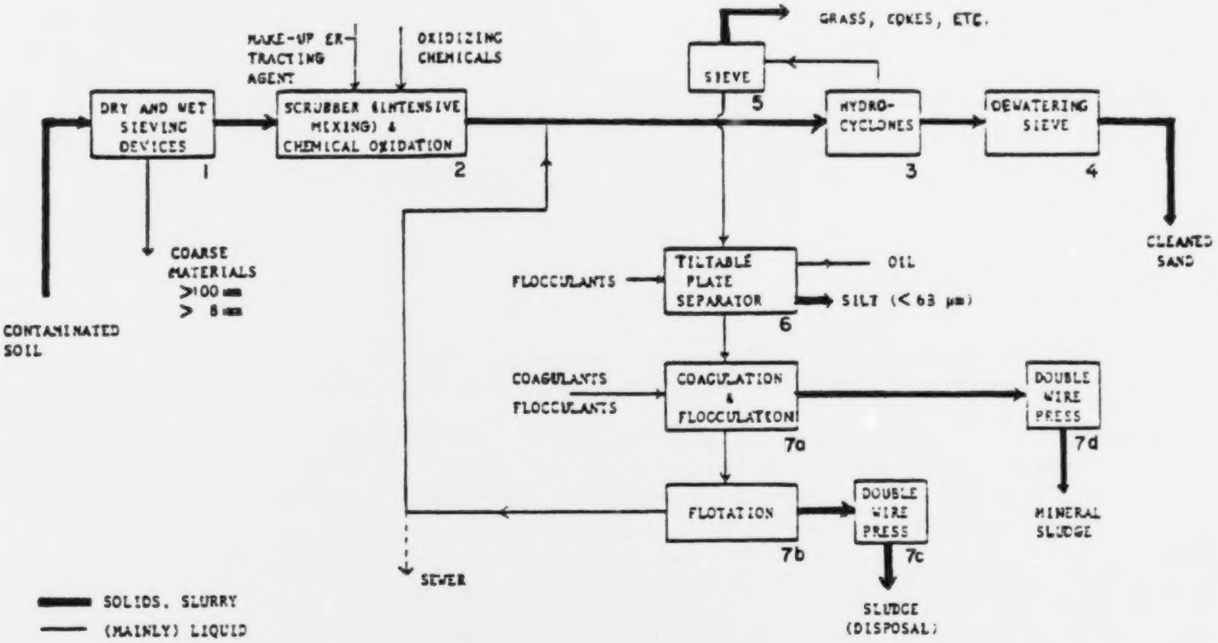

MAKE-UP EXTRACTING AGENT
OXIDIZING CHEMICALS
GRASS, COKES, ETC.
SIEVE
5
DRY AND WET SIEVING DEVICES
1
SCRUBBER (INTENSIVE MIXING) & CHEMICAL OXIDATION
2
HYDRO-CYCLONES
3
DEWATERING SIEVE
4
CLEANED SAND
COARSE MATERIALS
>100 mm
> 8 mm
CONTAMINATED SOIL
FLOCCULANTS
TILTABLE PLATE SEPARATOR
6
OIL
SILT (< 63 μm)
COAGULANTS
FLOCCULANTS
COAGULATION & FLOCCULATION
7a
DOUBLE WIRE PRESS
7d
MINERAL SLUDGE
FLOTATION
7b
DOUBLE WIRE PRESS
7c
SLUDGE (DISPOSAL)
SEWER
SOLIDS, SLURRY
(MAINLY) LIQUID

Figure 1. Process scheme of the installation of Heijmans Milieutechniek B.V.

Performance: The firm claims the following potential fields of application:

- Cyanides;
- Water immiscible and low-density (< 1000 kg/m^3) hydrocarbons;
- Heavy metals; or
- Combinations of these types of contaminant.

The soil should preferably contain less than 30 percent of fine solids (< 63 um) and humus-like compounds. At this time, the results of a number of test runs are available. Table 3 gives some examples.

INTERNATIONAL TECHNOLOGY FACT SHEET (continued)

TABLE 1. SOME RESULTS OF TEST RUNS EXECUTED WITH THE EXTRACTIVE INSTALLATION OF HEIJMANS

Contaminant	Initial concentration (mg/kg)	Concentration after treatment (mg/kg)	Removal efficiency (%)
Mineral oil	3.000 - 8.000	90 - 120	Approx. 98
Galvanic CN	450	15	Approx. 94
Zn	1.600 - 3.200	300 - 500	Approx. 83
Cd	66 - 125	5 - 10	Approx. 92
Ni	250 - 890	85 - 95	66 - 89

Limitations: Limited applicability to a number of toxic compounds.

Economics: 150 to 250 Dfl/tonne
Dfl 1 = $0.3 (June 1985)

Status: Full-scale plant since Spring of 1985. Ten to 15 tonnes soil/hr. Whole installation has been constructed in containers and is transportable.

Recommendations: Site visit recommended.

Reference: TNO - Assink, J.W. and W.J. van Den Brink. 1st International TNO/BMFT Conference on Contaminated Soil. November 11-15, 1985. Utrecht, The Netherlands. Published by Martinus Nijoff Publishers, Boston, MA. 1986.

INTERNATIONAL TECHNOLOGY FACT SHEET

Process: HWZ Bodemsanering Mobile Soil Extraction Plant

Type of Treatment: Physical/Chemical

Country: The Netherlands

Institution/Contact:
H.C.M. Breck
HWZ Bodemsanering
Vanadiumweg 5
3812 PX Amersfoort,
The Netherlands
Tel: 033-1 3844

Function: Soil washing.

Description: HWZ Bodemsanering B.V. has developed this plant for the cleaning of sandy soil in cooperation with TNO. A simplified process scheme is given in Figure 1. The following steps may be distinguished:

1. Separation of coarse materials (10 mm).
2. Intensive mixing of soil and water in order to disperse all soil particles and to scour off the contaminants (scrubbing).
3. Washing of the soil with a suitable extracting agent (NaOH) in up-flow column (jet-sizing). The bottom stream consists of sand particles larger than approximately 100 um.
4. Dewatering of the cleaned soil.
5. Separation of coarse, low-density materials, e.g., cokes.
6. Separation of silt (approximately 50 to 100 um) by hydrocyclones. This fraction is normally fed to the dewatering sieve, but may also be handled separately.
7. The spent extracting agent is cleaned in a number of steps. Cleaning is carried out by pH-adjustment, coagulation, flocculation, sludge separation in a tiltable plate separator, removal of the surplus of added iron by aeration and flotation, and finally a last pH-adjustment. The cleaned extracting agent is recirculated to a great extent.

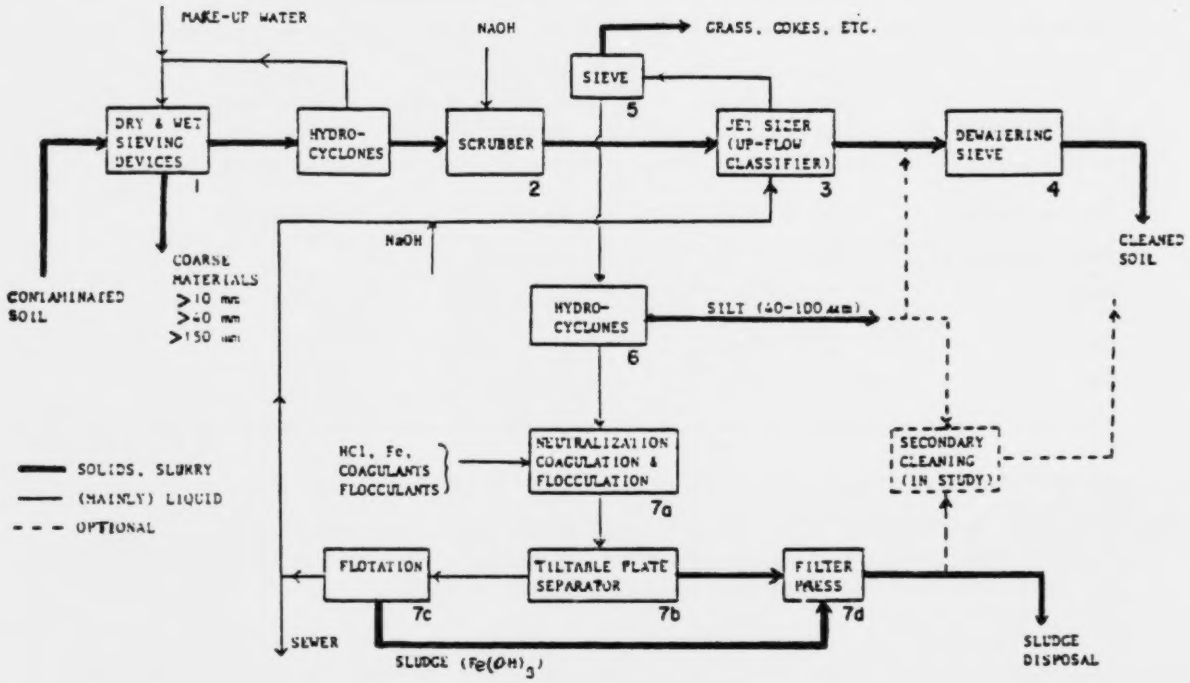

MAKE-UP WATER
NAOH
GRASS, COKES, ETC.
SIEVE
5
DRY & WET SIEVING DEVICES
1
HYDRO-CYCLONES
SCRUBBER
2
JET SIZER (UP-FLOW CLASSIFIER)
3
DEWATERING SIEVE
4
CLEANED SOIL
CONTAMINATED SOIL
COARSE MATERIALS
>10 mm
>40 mm
>150 µm
NaOH
HYDRO-CYCLONES
6
SILT (40-100 µm)
SOLIDS, SLURRY
(MAINLY) LIQUID
OPTIONAL
HCl, Fe, COAGULANTS FLOCCULANTS
NEUTRALIZATION COAGULATION & FLOCCULATION
7a
SECONDARY CLEANING (IN STUDY)
FLOTATION
7c
TILTABLE PLATE SEPARATOR
7b
FILTER PRESS
7d
SEWER
SLUDGE (Fe(OH)3)
SLUDGE DISPOSAL

Figure 1. Process scheme of the installation of HWZ Bodemsanering B.V.

Performance: The plant was initially developed for the cleaning of soil contaminated with cyanides. Besides cyanides, the potential applicability of the installation is conformable to Table 1. Thus, the installation may be considered for the purpose of cleaning soil contaminated with mineral oils, aromatics, PNAs, some chlorinated hydrocarbons, cyanides, and/or heavy metals. Some of the results obtained thus far are given in Table 1.

TABLE 1. SOME RESULTS OF TEST RUNS EXECUTED WITH THE EXTRACTIVE INSTALLATION OF HWZ BODEMSANERING

Contaminant	Initial concentration (mg/kg)	Concentration after treatment (mg/kg)	Removal efficiency (%)
CN (gaswork)	100 - 200	Approx. 10	Approx. 95
PNA (gaswork)	36	0,7	98
EOCl	20 - 24	0,3-0,5	98 - 99
Zn	81	27	67
Pb	Approx. 100	Approx. 25	Approx. 75

Limitations: Applicable to a limited number of toxic compounds. The sludge must be disposed of. The company is considering plans to incinerate the sludge in a fluidized bed of incinerator at 2650°F.

Also, the most troublesome step in the process is the separation between the fine mineral fraction (approximately 30 to 65 um) and the extracting agent. The best results were obtained with flocculation and filtration.

Economics: 150 to 250 Dfl/ton
Dfl 1 = $0.3 U.S. (June 1985)

Status: Full-scale operation since Autumn of 1984. Capacity: 20 ton/hr.

Recommendations: Site visit recommended.

Reference: TNO - Assink, J.W. and W.J. van Den Brink. 1st International TNO/BMFT Conference on Contaminated Soil. November 11-15, 1985. Utrecht, The Netherlands. Published by Martinus Nijoff Publishers, Boston, MA. 1986.

INTERNATIONAL TECHNOLOGY FACT SHEET

Process: Ecotechniek Soil Washing Process

Type of Treatment: Physical

Country: The Netherlands

Institution/Contact:
C. P. Pronk
Ecotechniek
Utrecht, Groenewoudesedijk
Postbus 39, 3454 ZG De Meern
Netherlands
Tel.: 030-957922

Function: Soil washing.

Description: Ecotechniek B.V.--A simplified process scheme is given in Figure 1. The process roughly comprises the following steps:

1. The contaminated sand is slurried up with recycle water and (indirectly) heated with steam up to a maximum of 90°C. Oil is dispersed in the water; any floating oil is skimmed off.

2. Separation of sand particles.

3. Dewatering of sand by natural draining.

4-5. Oil-containing process water is cleaned in two steps; separation of particles and oil thicker than water and, subsequently, skimming of floatable fractions.

The temperature of the system is dependent on the type of oil to be separated.

Performance: The installation is especially suitable for sand heavily contaminated with (crude) oil, preferably less dense than water. Thus far, experience has been gained in treating 5,000 tonnes of beach sand contaminated by an oil spill. Sand containing 200,000 mg/kg of oil could be cleaned to a final concentration of 20,000 mg/kg which resulted, therefore, in a removal efficiency of 90 percent. The treated sand is used in the preparation of asphalt.

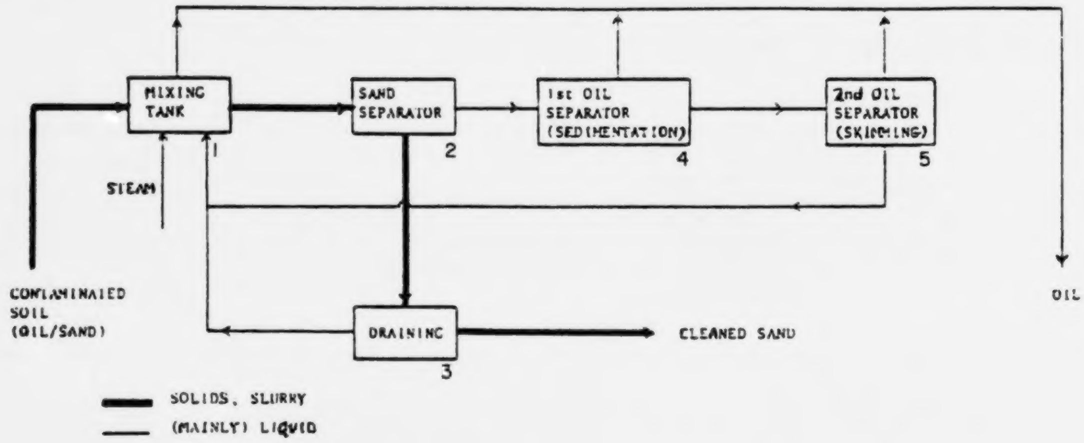

MIXING TANK
1
SAND SEPARATOR
2
1st OIL SEPARATOR (SEDIMENTATION)
4
2nd OIL SEPARATOR (SKIMMING)
5
STEAM
CONTAMINATED SOIL (OIL/SAND)
DRAINING
3
CLEANED SAND
OIL
SOLIDS, SLURRY
(MAINLY) LIQUID

Figure 1. Process scheme of the hot-water washing plant of Ecotechniek B.V.

Limitations: Specifically applicable to certain toxic constituents (see "Performance").

Economics: 150 to 250 Dfl/ton
Dfl 1 = $0.3 U.S. (June 1985)

Status: Ecotechniek has had a so-called thermal washing installation available for "several years" (time of article 1985).
Capacity: 20 ton/hr.

Recommendations: Check progress.

Reference: TNO - Assink, J.W. and W.J. van Den Brink. 1st International TNO/BMFT Conference on Contaminated Soil. November 11-15, 1985. Utrecht, The Netherlands. Published by Martinus Nijoff Publishers, Boston, MA. 1986.

INTERNATIONAL TECHNOLOGY FACT SHEET

Process: Thermal Treatment of Soil in the Netherlands (Overview)

Type of Treatment: Thermal

Country: The Netherlands

Institution/Contact: Ms. E.R. Soczo
RIVM
Antonie van Leeuwenhoeklaan 9,
Postbus 1
3720 BA Bilthoven
The Netherlands
Tel.: 030-743060

Function: Soil treatment techniques in the Netherlands - thermal treatments generally based on rotary kiln technology.

Description: This discussion of thermal soil treatment processes is taken from attachments of the March 1987 NATO/CCMS Pilot Study Report. Specific details appear in Fact Sheets that follow. Specifically, in regard to thermal treatment, the operational full-scale thermal plants in the Netherlands are listed in Table 1.

Treatment results of the plants are summarized in Table 2. On the basis of these results it can be concluded that thermal treatment is suitable for the destruction of organic contaminants such as petroleum compounds, benzene, toluene, ethylbenzene, and xylenes (BTEX), polycyclic aromatics (PCAs), and cyanides. The destruction efficiencies are very high in most cases (98 to 99.5 percent). (However, these calculated destruction efficiencies could be different from actual efficiencies because in many cases the calculations had to be done from a range of concentrations instead of an average concentration.) On the basis of laboratory results it is expected that some of the existing plants may be able to effectively treat soil contaminated with pesticides, such as lindane (-hexachlorocyclohexane). However, the only group of contaminants that cannot be destroyed by thermal techniques are the inorganics, e.g., heavy metals.

Description (cont.):

TABLE 1. OPERATIONAL THERMAL PLANTS (MARCH 1987)

Name of Company		Capacity (ton/year)[a]	Costs Dfl[b]/ton
ATM B.V.		60,000[c]	100-180
Boskalis Esdex Bodemsanering B.V.		4,000[d]	100-180
Broerius B.V. Bodemsanering		25,000	80-190
Ecotechniek B.V.	1st installation:	55,000	
	2nd installation:	80,000	100-180
NBM Bodemsanering B.V.		60,000	100-180

[a] On the basis of 8-hr/day.
[b] This plant is designed for 24-hr/day operation.
[c] The fluidized bed combustion unit of Boskalis Esdex is a pilot plant.
[d] Dfl 1 is approximately U.S. $0.50 (March 1987).

Experience with thermal plants has shown that this technology can be used for a variety of soil types, including soils with high concentrations of humus, peat, loam, or clay. The thermal treatments lead to a change of the soil structure: the higher the temperature, the greater the combustion of organic particles (humus). However, generally soil texture does not change dramatically because the treated soil is mixed with the dust removed from the flue gases. There is potential for the reuse of thermally treated soils.

Performance: As shown in Table 2, excellent performance is possible with thermal treatment equipment.

Limitations: Costs and metal residuals are principal limitations.

TABLE 2. TREATMENT RESULTS FROM OPERATIONAL THERMAL PLANTS (MARCH 1987)

		Concentration (mg/kg dry weight)	
Type of Soil	Contaminants	Initial	Final
sand	diesel fuel	1,000-50,000	100-640
	gasoline	1,000-30,000	<20
clay	oil	0-1,000	<200
sand > 10% peat	CN complex	200-10,000	1-4*
several	CN	0-1,000	0-7
sand	BTEX	0-400	<1
clay	BTEX	0-500	<1
sand	PCAs	0-1,000	<3
sand > 10% peat	PCAs	700-4,000	0.1*
sand > 10% loam	PCAs	0-8,000	<0.01

* Thermal treatment by fluidized bed furnace.

NOTES:

1. Specifications of the types of oil and the types of cyanides were often not mentioned.
2. BTEX: benzene, toluene, ethylbenzene, xylenes.
3. Common measurements of PCAs are the 6 PCAs of Borneff or the 16 polycyclic aromatics (volatile organics) (PCAs) according to U.S. EPA.
4. CN: cyanides.

INTERNATIONAL TECHNOLOGY FACT SHEET (continued)

Economics: The costs of thermal treatment vary between Dfl 80 to 190/ton (1 Dfl = $0.5 U.S. dollar, March 1987), and depend primarily on the moisture content of the soil and the type of contaminants.

Status: Thermal destruction is demonstrated technology.

Recommendations: New developments should be followed but, technology appears to be similar to that available in the United States. Monitor results of NATO/CCMS study.

Reference: NATO/CCMS Pilot Study; Demonstration of Remedial Action Technologies for Contaminated Land and Ground Water. 1st International Workshop, Karlsruhe, Federal Republic of Germany. March 16-20, 1987.

INTERNATIONAL TECHNOLOGY FACT SHEET

Process: ATM Rotary Kiln for Soils

Type of Treatment: Thermal

Country: The Netherlands

Institution/Contact: Editor: W.B. de Leer
Delft University of Technology
Laboratory for Analytical Chemistry

Function: Rotary kiln.

Description: The ATM Process--The ATM process consists essentially of two rotary kilns and an incinerator. In the first kiln the moisture content of the soil is reduced to about 2/3 of its original value, while in the second kiln, the soil is heated to its final temperature with an oil burner.

The soil is in direct contact with the flames which have a temperature of about 1500°C. To prevent explosions, the O_2 content in the oven must be kept below 10 percent, which makes high demands on the seal of the connections. The burner gases, together with the volatilization products, are incinerated at 850°C with a residence time of 0.7 seconds. Flue gas cleaning is completed by means of a bag filter to remove fly ash. A future extension with a catalytic afterburner is anticipated to allow the treatment of soil contaminated with cyanides. The emissions of hydrocarbons (CxHy), carbon monoxide (CO), and dust are being continuously monitored by process analyzers.

The installation has been designed for the next two typical cases:

	Case A	Case B
Capacity (t/hr)	28.9	17.1
Moisture content (% w/w)	15	10
Contamination degree (% w/w)	1.25	4.2
Final soil temperature (°C)	600	600
Maximum thermal load: 75.6 GJ/hr		

If necessary, the final temperature of the soil can be elevated up to 800°C.

Performance: Capable of cleaning soils to below (A) levels set by the Dutch government (see Table 1).

TABLE 1. DUTCH REFERENCE LEVELS USED FOR THE JUDGMENT OF SOIL CONTAMINATION

Component	Concentration level (mg/kg dry weight) A	B	C
Polycyclic aromatic hydrocarbons (total)	1	20	200
Mononuclear aromatics (total)	0.1	7	70
Mineral oil	100	1000	5000
Cyanide (total complex)	5	50	500

A = Background level uncontaminated soil.
B = Level which necessitates further investigation.
C = Level which necessitates a sanitation investigation.

Limitations: Metals not removed by thermal treatment. Organochlorine compounds may decompose to toxic chlorinated dibenzodioxins.

Economics: Costs for thermal cleaning of soil are reportedly Df 100 to 180/ton ($30 to 60 U.S.) depending on the type of contamination and type of soil.

Status: Full-scale plant since September 1985.

Recommendations: Check status.

Reference: TNO - Assink, J.W. and W.J. van Den Brink. 1st International TNO/BMFT Conference on Contaminated Soil. November 11-15, 1985. Utrecht, The Netherlands. Published by Martinus Nijoff Publishers, Boston, MA. 1986.

INTERNATIONAL TECHNOLOGY FACT SHEET

Process: BOSKALIS-ESDEX Fluidized Bed Furnace for Soils

Type of Treatment: Thermal

Country: The Netherlands

Institution/Contact:
Ms. R. Haverkamp Begemann
Boskalis-Esdex Bodemsanering
P.O. Box 4234
3006 AE Rotterdam
Tel.: 010-524544

Function: Fluidized bed destruction.

Description: In the BOSKALIS-ESDEX process the contaminated soil is treated in a fluidized bed furnace at a temperature of 800 to 900°C. The furnace consists of two compartments, the fluidized bed and the freeboard. On a pilot-plant scale, the fluidized bed contains 1.5 tons of material with a particle size of 0.1 to 1.2 mm. Contaminated soil is fed continuously (2 t/h) to the bed, but the cleaned material is removed batch-wise. The average residence time in the heated zone is 1 hour.

After the initial ignition and heating phase, oil is injected directly in the fluidized bed with two oil guns. No open flames are present; the mixture of oil, air, and contaminated soil glows evenly at an average temperature of 800°C. Higher temperatures must be prevented as above 1000°C the soil starts to sinter, while below a temperature of 630°C the process shuts off automatically. The temperature in the freeboard is approximately the same as in the fluidized bed. The average residence time of the gases in the freeboard is 6 seconds, which is sufficient for complete incineration.

A cyclone removes dust particles down to 100 to 150 um, smaller particles are removed by a bag filter. About 50 to 80 percent of the supplied soil is removed from the bottom of the fluidized bed as an organic-free material. Also, peat and humus will disappear after having added energy to the process. About 15 to 30 percent is removed from the cyclone and a maximum of 5 percent from the bag filter.

Performance: Capable of cleaning soils to below (A) levels set by the Dutch government (see Table 1).

TABLE 1. DUTCH REFERENCE LEVELS USED FOR THE JUDGMENT OF SOIL CONTAMINATION

Component	Concentration level (mg/kg dry weight)		
	A	B	C
Polycyclic aromatic hydrocarbons (total)	1	20	200
Mononuclear aromatics (total)	0.1	7	70
Mineral oil	100	1000	5000
Cyanide (total complex)	5	50	500

A = Background level uncontaminated soil.
B = Level which necessitates further investigation.
C = Level which necessitates a sanitation investigation.

Limitations: Metals are not removed by thermal treatment. Organochlorine compounds may decompose to toxic chlorinated dibenzodioxins.

Economics: Costs for thermal cleaning of soil are Df 100 to 180 ($30 to 60 U.S.) per ton, depending on the type of contamination and type of soil.

Status: Pilot-plant stage completed.

Recommendations: Monitor program.

Reference: TNO - Assink, J.W. and W.J. van Den Brink. 1st International TNO/BMFT Conference on Contaminated Soil. November 11-15, 1985. Utrecht, The Netherlands. Published by Martinus Nijoff Publishers, Boston, MA. 1986.

INTERNATIONAL TECHNOLOGY FACT SHEET

Process: ECOTECHNIEK Rotating Kiln Tubular Furnace for Soils

Type of Treatment: Thermal

Country: The Netherlands

Institution/Contact: C.P. Pronk
Ecotechniek
Utrecht, Groenewoudesedijk
Postbus 39, 3454 ZG De Meern
The Netherlands
Tel.: (030) 957922

Function: Rotary kiln.

Description: The ECOTECHNIEK Process--The soil enters the rotating tubular furnace and is heated directly in the first half of the furnace to about 125°C with the return gases from the incinerator. The water evaporates from the soil in this step together with the volatile organic compounds such as benzene, etc. In the second half of the furnace, the soil is in direct contact with the flame of one single burner and the hot burner gases. When the soil leaves the furnace (total residence time = 10 minutes), the soil temperature is 300 to 500°C, depending on the adjustment of the burner. The installation is designed for a maximum soil temperature of 550°C at a capacity of 50 ton/hr when sandy soil is treated with a maximum of 12 percent of water and 1 percent of organic contamination.

The burner gases and the volatilized contamination are incinerated at a maximum temperature of 1300°C. Dust formed in the rotating tube furnace and in the incinerator is removed by a multicyclone and a gas scrubber, respectively. In this step, acidic products such as sulphur dioxide and hydrochloric acid are also removed. The water from the gas scrubber is used for moistening the cleaned soil to a water content of 8 percent. The dust is returned to the treated soil.

Performance: Capable of cleaning soils to below the (A) level set by the Dutch government (see Table 1).

TABLE 1. DUTCH REFERENCE LEVELS USED FOR THE JUDGMENT OF SOIL CONTAMINATION

Component	Concentration level (mg/kg dry weight)		
	A	B	C
Polycyclic aromatic hydrocarbons (total)	1	20	200
Mononuclear aromatics (total)	0.1	7	70
Mineral oil	100	1000	5000
Cyanide (total complex)	5	50	500

A = Background level uncontaminated soil.
B = Level which necessitates further investigation.
C = Level which necessitates a sanitation investigation.

Limitations: Metals not removed by thermal treatment. Organochlorine compounds may decompose to toxic chlorinated dibenzodioxins.

Economics: Costs for thermal cleaning of soil are Df 100 to 180/ton ($30 to 60 U.S.) depending on the type of contamination and type of soil.

Status: Full-scale operation since 1982.

Recommendations: Check status.

Reference: TNO - Assink, J.W. and W.J. van Den Brink. 1st International TNO/BMFT Conference on Contaminated Soil. November 11-15, 1985. Utrecht, The Netherlands. Published by Martinus Nijoff Publishers, Boston, MA. 1986.

INTERNATIONAL TECHNOLOGY FACT SHEET

Process: NBM Indirectly-Heated Tube Furnace for Soils

Type of Treatment: Thermal

Country: The Netherlands

Institution/Contact: C.M.A. Van Veldhoven
NBM Bodemsanering B.V.
Zouweg 23
2516 AK The Hague, Netherlands
Tel.: 070-814331

Function: Indirectly heated rotary kiln.

Description: The NBM process is the only thermal process which uses an indirectly heated tube furnace (see Figure 1). Because the burner gases are not mixed with the volatilization products, the incinerator can be designed on a smaller scale. A low flow of inert gas is maintained in the tube furnace, which produces less dust than in the case of direct heating systems.

Much attention has been paid to the air-tight sealing of the rotary tube furnace from the stationary devices for the soil input and output. The two flanges of the rotating and the stationary parts are pressed together by a flexible bellows (see Figure 1). Two rings of a high temperature resistant synthetic material and a carbon ring make the seal tight. The spaces between the rings are pressurized with inert gas to prevent the leaking of gases from the furnace to the environment.

The pilot plant has a capacity of 0.5 ton/hr, which gives a residence time in the furnace of approximately 20 min. The maximum soil temperature at the end of the furnace is 900°C. Dust is removed in a cyclone and the volatilized products are incinerated at a maximum temperature of 1,400°C with a residence time of about 1 sec.

The production plant has a maximum input of 15 tons/hr. In order to bring the capacity of the plant to the desired level, an extra pre-dryer has been added to the pilot plant design. The soil temperature is 600°C and the incinerator temperature is 1100°C with a residence time of 1 sec.

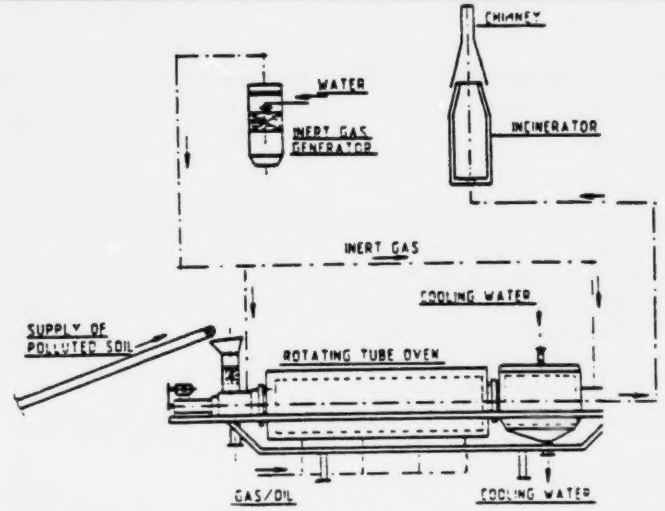

CHIMNEY
WATER
INERT GAS GENERATOR
INCINERATOR
INERT GAS
COOLING WATER
SUPPLY OF POLLUTED SOIL
ROTATING TUBE OVEN
GAS/OIL
COOLING WATER

Figure 1. Process scheme NBM thermal treatment pilot-plant.

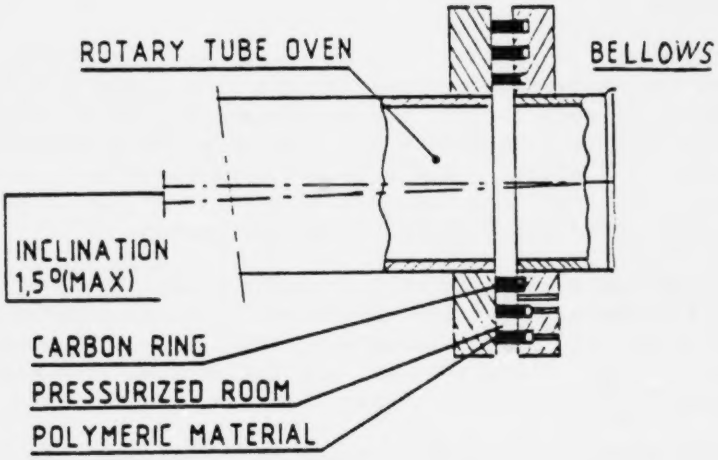

ROTARY TUBE OVEN
BELLOWS
INCLINATION
1,5°(MAX)
CARBON RING
PRESSURIZED ROOM
POLYMERIC MATERIAL

Figure 2. Gas-tight flexible coupling between the rotary and stationary parts of the NBM indirectly heated rotating tube furnace (patented by SMIT OVENS BV).

Performance: Capable of cleaning soils to below (A) levels set by the Dutch government (see Table 1).

TABLE 1. DUTCH REFERENCE LEVELS USED FOR THE JUDGMENT OF SOIL CONTAMINATION

Component	Concentration level (mg/kg dry weight)		
	A	B	C
Polycyclic aromatic hydrocarbons (total)	1	20	200
Mononuclear aromatics (total)	0.1	7	70
Mineral oil	100	1000	5000
Cyanide (total complex)	5	50	500

A = Background level uncontaminated soil.
B = Level which necessitates further investigation.
C = Level which necessitates a sanitation investigation.

Limitations: Metals are not removed by thermal treatment. Organochlorine compounds may decompose to toxic chlorinated dibenzodioxins.

Economics: Costs for thermal cleaning of soil are reported at Dfl 100 to 180/ton ($30 to 60 U.S.) depending on the type of contamination and type of soil.

Status: Pilot-plant stage completed in 1984. In October 1986, the production plant was said to be in operation.

Recommendations: Check status.

References: NBM Bodemsanering BV - Netherlands. Brochure discussing thermal treatment and soil cleaning operations. October 1986.

TNO - Assink, J.W., and W.J. van Den Brink. 1st International TNO/BMFT Conference on Contaminated Soil. November 11-15, 1985, Utrecht, The Netherlands. Published by Martinus Nijoff Publishers, Boston, MA. 1986.

INTERNATIONAL TECHNOLOGY FACT SHEET

Process: Landfarming Efforts in the Netherlands

Type of Treatment: Biological

Country: The Netherlands

Institution/Contact: Ms. E.R. Soczō
National Institute of Public Health
and Environmental Hygiene (RIVM)
Laboratory for Waste and Emission Research
Antonie van Leeuwenhoeklaan 9,
Postbus 1
3720 BA Bilthoven, The Netherlands
Tel.: 030-743060

Function: Biological degradation of pollutants such as gas oil, fuel oil, cutting oils, and PCAs.

Description: Landfarming, as a means of restoring contaminated soils, has reportedly achieved some success in the Netherlands. Although processing details are not available, good results have been achieved in Government-sponsored programs for many contaminants, including oil compounds and polycyclic aromatics.

Landfarming is being carried out at the location of a Waste Disposal Company in Wijster, Province of Drenthe as a NATO/CCMS Pilot Study project. The aim of this project is to improve landfarming methods in practice.

Performance:

Type of oil	Initial concentration (ppm)	Concentration after one growing season (ppm)	Concentration after two growing seasons (ppm)
Gas oil	1,800	400	--
Fuel oil	6,800	800	300
Cutting oil	2,400	800	--
Mineral oil	1,100	1000	400
PCAs	300	100[a]	70[b]

[a] Time period is 2 months.
[b] Time period is 16 months.

These data are based on a growing season entailing the warmest period of the year (4 to 6 months).

Limitations: Not applicable for crude oil or higher PCAs, such as benzo(b)fluoranthene and benzo(a)pyrene. Isolation of treatment area needed to prevent migration. Low residual concentrations not shown.

Economics: No economic data are available.

Status: Recently, at least three companies have restored different contaminated sites by means of landfarming, and the results for soil contaminated with oil compounds (excluding crude oil) were promising. In sum, landfarming has been developed to an operational level but has yet to be optimized.

As of March 1987, cleanup at the Wijster site has been finished regarding gas oil. Cleanup of crude oil is still going, and field study has yet to start regarding halogenated hydrocarbons.

Recommendations: Further information on treatment and economics is needed. Monitor results of NATO/CCMS work.

Reference: NATO/CCMS Pilot Study; Demonstration of Remedial Action Technologies for Contaminated Land and Ground Water. 1st International Workshop, S. Karlsruhe, Federal Republic of Germany. March 16-20, 1987.

INTERNATIONAL TECHNOLOGY FACT SHEET

Process: In Situ Biorestoration of Soil Contaminated with Gasoline

Type of Treatment: Biological

Country: The Netherlands

Institution/Contact: E.R. Soczo and R. Van Den Berg
National Institute of Public
Health & Industrial Hygiene (RIVM)
3720 BA Bilthoven, The Netherlands
Tel.: 030-743060

Function: This NATO/CCMS demonstration study, started in 1985, will determine the effectiveness of in situ biodegradation of gasoline in deeper soil layers. If effective, it is expected that biodegradation will appreciably reduce costs of traditional (thermal and extraction cleanup) processes.

Description: This project (at Aspen, in the province of Noord-Brabant) is aimed at optimizing the treatment of deeper layers of soils contaminated with gasoline (and small amounts of lead) by enhancing microbial activity. The stimulation of biodegradation will be carried out to mimic the most favorable conditions for microbial degradation as determined under laboratory conditions. Before in situ biorestoration can begin, the contaminated location must be isolated hydrologically to avoid further dispersion of contaminants.

Factors important for biodegradation are addition of water and nutrients, adequate O_2, addition of microorganisms, increased soil temperature, improved contact between oil drops and microorganisms and, if necessary, adjust pH. Cleanup will be performed by circulating the ground water, which will be pumped from the saturation phase. Monitoring wells will be installed for the purpose of measuring contaminant transport and degradation, oxygen and nutrient levels, microbial activity, pH, water saturation, and temperature.

INTERNATIONAL TECHNOLOGY FACT SHEET (continued)

Performance: There is presently a lack of data with regard to full-scale projects, however, laboratory experiments conclude the following:

- The rate of microbial activity and degradation of petroleum product is low;
- Increased degradation is obtained by: saturation with water, and buffering;
- Nutrients must be available, but type of nitrogen is not important; and
- Addition of biodegradable detergents has little effect on availability of gasoline for microorganisms.

Limitations: Under the most favorable conditions in the laboratory, the microbial activity and rate of degredation of petroleum products (mainly gasoline) in contaminated soils is low.

Economics: The cost of reclamation by means of in situ biodegradation can be estimated when the laboratory experiments and site cleanup operation at the experimental site are completed.

Status: Selected as a NATO/CCMS Pilot Study demonstration technology (March 1987). Demonstration on full-scale began in 1987.

Recommendations: Oil products have been ranked as easily biodegradable in comparison to other contaminants, therefore, some successes in this area are likely. A site visit is recommended. Also, monitor results of the NATO/CCMS Pilot Study.

Reference: NATO/CCMS Pilot Study; Demonstration of Remedial Action Technologies for Contaminated Land and Ground Water. 1st International Workshop, S. Karlsruhe, Federal Republic of Germany. March 16-20, 1987.

INTERNATIONAL TECHNOLOGY FACT SHEET

Process: Bioreactor Research

Type of Treatment: Biological

Country: The Netherlands

Institution/Contact: Mr. G. J. Annokkee
TNO Div. of Technology for Society
Dept. of Process Technology
P.O. Box 342
7300 AH Apeldoorn, The Netherlands
Tel.: (055) 77 33 44

Function: Biological treatment of soil contaminated with substances of low biodegradability.

Description: Biological treatment techniques for site restoration are being actively studied in the Netherlands. These techniques are still in the development stage; most projects were begun in 1985.

Research into the development of bioreactors has been ongoing for the last 2 years. The development of bioreactors is important for the biological treatment of contaminants of low biodegradability; for instance, halogenated hydrocarbons such as methylene chloride, and soils that are generally difficult to treat, such as clay.

Bioreactors have better possibilities for process control, better contact between contaminants and microorganisms due to an improved homogenization of the soil (e.g. in slurry reactors) and the possibility for the application of specially cultivated microorganisms.

Based on the first laboratory results, the following conclusions can be drawn:

- Biodegradation of halogenated hydrocarbons is strongly enhanced by the addition of selected microorganisms;
- Biodegradation is enhanced in a soil/water slurry versus in water only; and
- For the treatment of various types of soils, different process pathways or reactor systems have to be developed.

Description (cont.):

Further Research--On the basis of this research and research on landfarming, further investigation into the field of biological soil remediation will be beneficial. In the near future, research will be conducted on the following subjects:

- The influence of physical and chemical soil dynamics on landfarming treatment;
- The possibilities of adding and maintaining specific cultivated microorganisms in different treatment systems;
- The possibilities of biological treatment of soil contaminated with chlorinated hydrocarbons;
- The development of bioreactor systems; and
- The development of computer models which can be used to simulate the effectiveness of biological soil treatment techniques.

New projects investigating the above topics were planned for 1987. These projects are expected to be done in cooperation with various institutes and universities. Engineering consultants and companies will also participate in an early stage in several projects to develop treatment techniques. The supervision and coordination of these research projects will also be the responsibility of the RIVM/LAE organization.

Performance: Preliminary results show that -hexachlorocyclohexane (-HCH) degrades well under aerobic conditions (in an aerated slurry). A reduction of -HCH was not observed.

Limitations: A dewatering step is usually necessary with bioreactors.

Economics: To be determined.

Status: Development stages.

Recommendations: Monitor results and discuss with TNO.

Reference: NATO/CCMS Pilot Study; Demonstration of Remedial Action Technologies for Contaminated Land and Ground Water. 1st International Workshop, S. Karlsruhe, Federal Republic of Germany. March 16-20, 1987.

INTERNATIONAL TECHNOLOGY FACT SHEET

Process: Reclamation of Contaminated Soil with a Bioreactor

Type of Treatment: Biological

Country: The Netherlands

Institution/Contact: K. Ch. A.M. Luyben and R.H. Kleijntjens
Department of Biochemical Engineering
Delft University of Technology
Julianalaan 67,
2628 BC Delft, The Netherlands
Tel.: (015) 78 23 53

Function: A faster, controllable alternative to landfarming.

Description: In the reactor, a three-phase slurry is sustained (soil-water-air). Microorganisms, primarily Pseudomonas species consume the organic pollutants, which are adsorbed to the soil particles, converting them to biomass, CO_2 and H_2O. The particles are kept in suspension by the turbulent liquid motion created by injecting gas in the bottom of the reactor (see Figure 1). Figure 2 shows a flow sheet of a possible configuration of unit operations in a full-scale process.

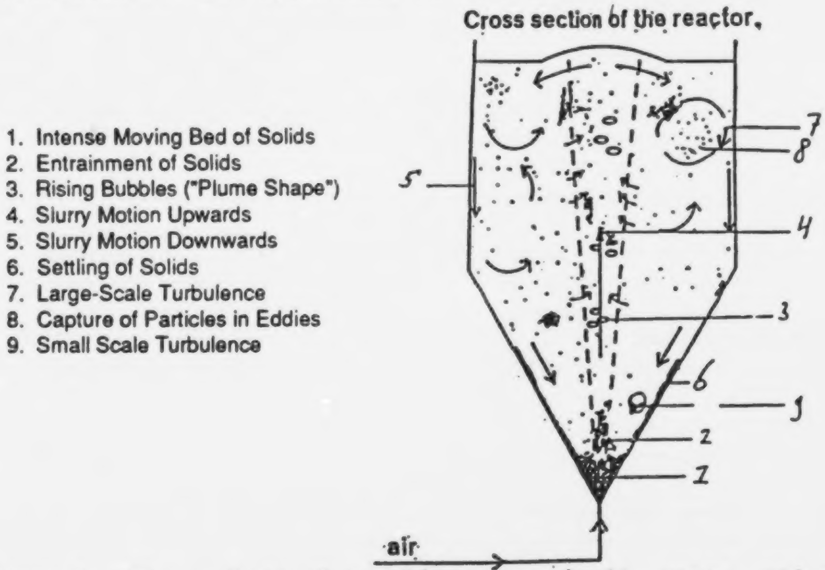

Cross section of the reactor,
1. Intense Moving Bed of Solids
2. Entrainment of Solids
3. Rising Bubbles ("Plume Shape")
4. Slurry Motion Upwards
5. Slurry Motion Downwards
6. Settling of Solids
7. Large-Scale Turbulence
8. Capture of Particles in Eddies
9. Small Scale Turbulence
5
7
8
4
3
6
9
2
1
air

Figure 1. Three-phase slurry bioreactor (soil, water, and air).

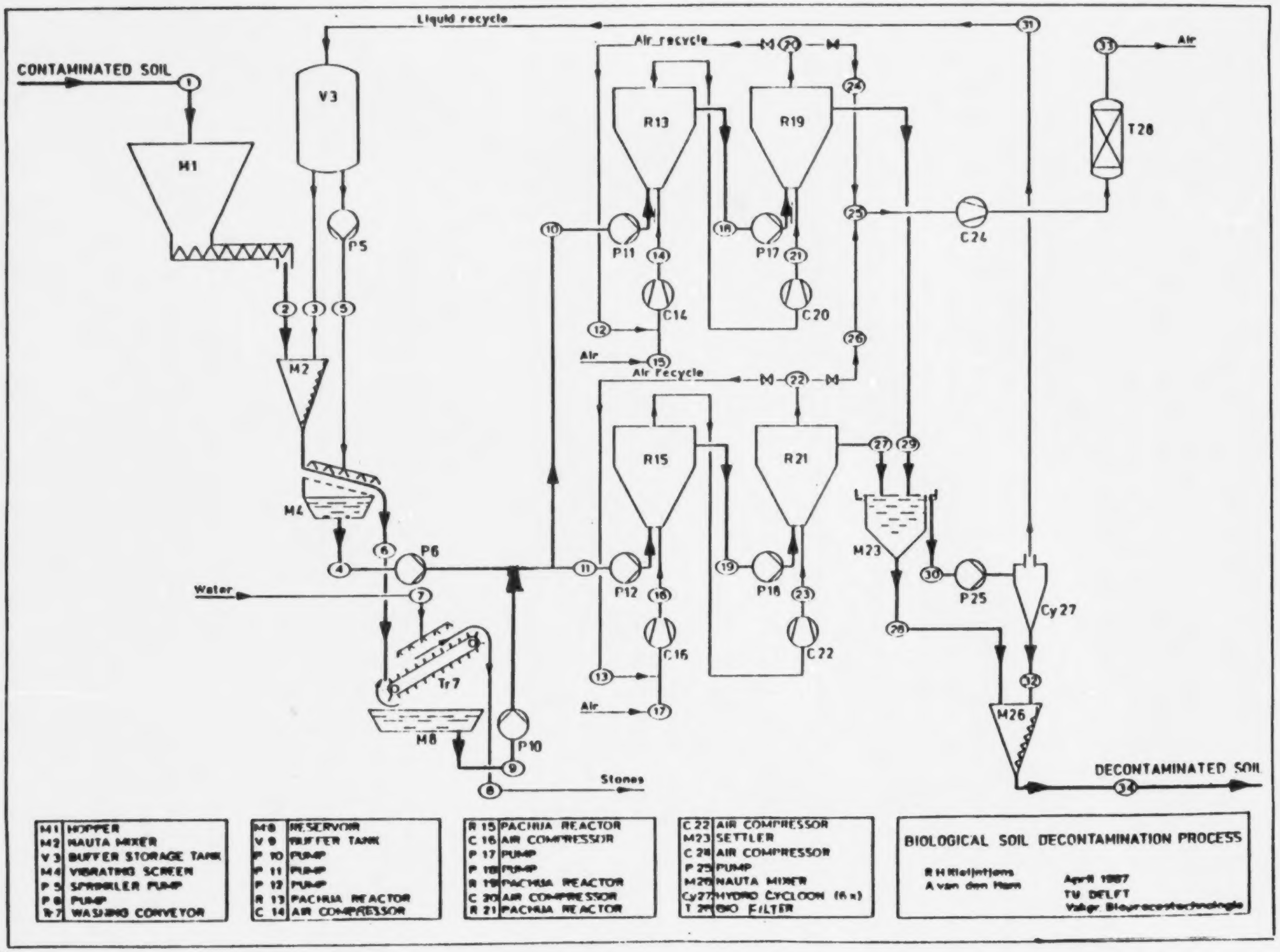

Liquid recycle
CONTAMINATED SOIL
1
M1
V3
P5
2
3
5
M2
M4
4
6
P6
Water
7
Tr7
M8
P10
9
8
Stones
10
11
P11
P12
12
13
14
15
16
17
Air
Air
C14
C16
Air recycle
Air recycle
R13
R15
R19
R21
18
19
P17
P18
20
21
22
23
C20
C22
24
25
26
27
29
M23
28
30
P25
C24
31
Cy27
32
M26
33
T28
Air
DECONTAMINATED SOIL
34
M1 HOPPER
M2 NAUTA MIXER
V3 BUFFER STORAGE TANK
M4 VIBRATING SCREEN
P5 SPRINKLER PUMP
P6 PUMP
Tr7 WASHING CONVEYOR
M8 RESERVOIR
V9 BUFFER TANK
P10 PUMP
P11 PUMP
P12 PUMP
R13 PACHUA REACTOR
C14 AIR COMPRESSOR
R15 PACHUA REACTOR
C16 AIR COMPRESSOR
P17 PUMP
P18 PUMP
R19 PACHUA REACTOR
C20 AIR COMPRESSOR
R21 PACHUA REACTOR
C22 AIR COMPRESSOR
M23 SETTLER
C24 AIR COMPRESSOR
P25 PUMP
M26 NAUTA MIXER
Cy27 HYDRO CYCLOON (6 x)
T28 BIO FILTER
BIOLOGICAL SOIL DECONTAMINATION PROCESS
R H Kleijntjens
A van den Ham
April 1987
TU DELFT
Vakgr. Bioprocestechnologie

Figure 2. Flow sheet of a proposed large-scale biological soil decontamination process.

INTERNATIONAL TECHNOLOGY FACT SHEET (continued)

Performance: Experiments have shown the possibility of reducing the concentration of contaminating compounds by more than 95 percent within a residence time of 3 days for soil. One study examined the possibilities of degradation of diesel fuel, by choosing four model chemicals, representing the n-alkane, the branched alkane, the alkene and the aromatic fraction. Within 3 days these chemicals are broken down with a conversion of 99 percent, which is sufficient to meet Dutch standards. On n-hexadecane the growth rate is 35 hr^{-1}. The yield is 1-1,5 gr biomass/gr n-hexadecane. The oxygen consumption rate in the mixed part of the ditch is very high. Therefore, the oxygen-transfer-rate coefficient (Kla) should be high too (6.10^{-3} sec^{-1}), which governs the amount of introduced air. For the other part of the reactor the amount of air follows the amount needed for suspending the solids.

Limitations: None reported.

Economics: It seems to be possible to degrade diesel fuel compounds and related compounds like petrol and non-halogenated solvents with a residence time of 3 to 4 days. Because investment costs of this technology are low, overall costs are also low. A rough economic evaluation resulted in a cost estimate of about f. 50,- per ton. Another advantage of the low investment costs is the possibility to install a reactor system and use it when necessary.

Status: These are the first tentative results of a 4-year laboratory project (1986-1990).

Recommendations: Update status.

References: Kleijntjens, R.H., Luyben, K. Ch. A.M., Bosse, M.A., and L.P. Velthuisen. "Process Development for Biological Soil Decontamination in a Slurry Reactor." 4th European Congress on Biotechnology 1987, Volume 1. Edited by O.M. Neijssel, R.R. van der Meer and K. Ch. A.M. Luyben. Amsterdam. 1987.

TNO - Assink, J.W., and W.J. van Den Brink. 1st International TNO/BMFT Conference on Contaminated Soil. November 11-15, 1985, Utrecht, The Netherlands. Published by Martinus Nijoff Publishers, Boston, MA. 1986.

INTERNATIONAL TECHNOLOGY FACT SHEET

Title: Electrochemical Treatment of Organohalogens

Type of Treatment: Electrochemical

Country: The Netherlands

Institution/Contact: Dr.-Ir. D. Schmal
TNO Division of Technology for Society
Department of Environmental Technology
P.O. Box 217
2600 AE Delft
Schoemakerstraat 97
2628 VK Delft, The Netherlands
Tel: 015 69 6087

Function: This technology electrochemically removes chlorine atoms from organic molecules, reducing their toxicity and increasing their biodegradability. It is used for the treatment of liquids with low concentrations (1 to 1,000 ppm) of toxic constituents.

Description: Dehalogenation of chlorinated organic compounds in low concentration aqueous solutions has been developed for the treatment of waste water and, if applicable, rinse water from polluted soils containing such compounds. Carbon fibers having a diameter of 10 um were selected as the optimal cathode due to their high specific surface area (SSA = 4×10^5 m^{-1}), availability, and relatively high overpotential for hydrogen evolution, which is favorable for the efficiency of the dehalogenation reaction.

A diagram of the flow-circuit is shown in Figure 1. The reactor consists of two compartments separated by a diaphram. The cathodic reduction of halogenated compounds results in the formation of non-halogenated compounds and chloride ions. Hydrogen evolution is a competing reaction, which decreases current efficiency. As a result, energy consumption is increased. This technology is applied in practice, however, to low concentrations (often less than 100 to 1,000 ppm) where energy consumption is not normally a factor of major importance (see Table 1).

This method is particularly suitable for wastewaters containing polar or ionic organochlorine compounds which are, in general, difficult to decontaminate by adsorption or stripping. Carbon adsorption, a possible treatment for chlorinated organic compounds, does not decrease the toxicity of the compounds as electrochemical treatment does. Combustion is not appropriate for the treatment of diluted wastewaters due to high transportation costs, the necessity of adding large quantities of fuel and the potential for corrosiveness of the liquids.

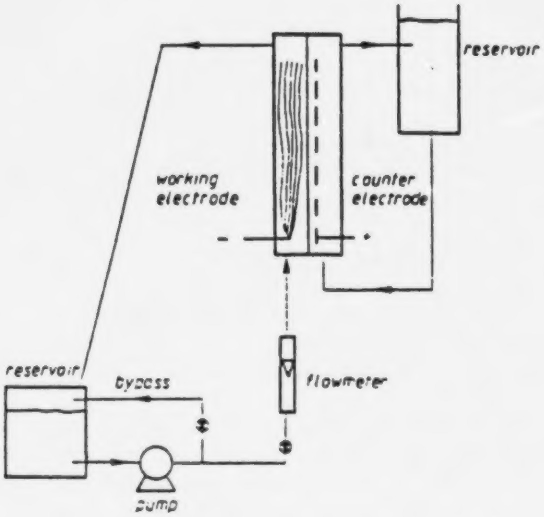


Figure 1. Diagram of flow-circuit.

TABLE 1. Energy Consumptions for the Removal of One Cl-Atom From a Compound at a Concentration of 100 ppm, a Molecular Weight of 250, and a Cell Voltage of 4V.

Current efficiency (%)	Energy consumed (kWh/m^3)
100	0.1
10	1
1	10
0.1	100
0.01	1,000

Performance: Dr. Schmal used Pentachlorophenol (PCP) as an example because it is a polar, halogenated, non-biodegradable compound with a very negative reduction potential. Electrolysis at 10 A of 1 liter of 50 ppm PCP in 0.1 M sodium sulphate/0.1 M sodium hydroxide solution caused the PCP concentration to decrease as shown in Figure 2. After 30 minutes of electrolysis, the PCP concentration was below the detection limit of 0.5 ppm, with a current efficiency for dehalogenation of 1 percent.

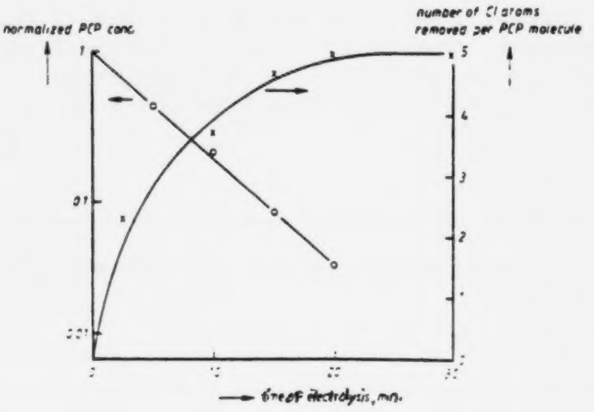
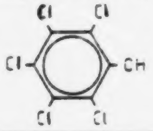


Figure 2. Relative PCP Concentration and Yield of Cl Ions per PCP Molecule During Electrolysis:

Structural formula:



Performance (cont.):

Addition of small quantities of quaternary ammonium compounds as surface active agents (such as octadecyltrimethyl ammonium chloride) improves the efficiency considerably. The addition of these micelle-forming compounds is patented (U.S. No. 4,443,309), and reportedly results in a 45 percent decrease in energy consumption. Irrespective of the molecular structure, Dr. Schmal found that it is possible to remove all Cl atoms from the organic molecule in aqueous solutions.

Limitations: Not applicable to high-concentration wastewaters due to high energy costs.

Economics: The consumption of energy is relatively high at about 50 kWh/m^3. After further development, 10 to 20 kWh/m^3 appears to be a realistic value. A treatment capacity of 100 L of wastewater/L reactor volume/hour should be attainable. Costs, therefore, should be about Dfl 10 per m^3 of wastewater.

Status: This technology has been studied using a batch-type, bench-scale reactor. Further investigations are planned in which a pilot reactor with a treatment capacity of about 100 L/hr will be tested. This second phase investigation will seek to decrease energy consumption, increase reaction rates, and predict long-term behavior.

Recommendations: Update status; site visit recommended.

References: Schmal, D., Van Erkel, J., de Jong, A.M.C.P., and P.J. van Duin. "Electrochemical Treatment of Organohalogens in Process Wastewaters." Proceedings of the 2nd European Conference on Environmental Technology, Amsterdam, The Netherlands. June 22-26, 1987.

Technical Insights, Inc. New Methods for Degrading/Detoxifying Chemical Wastes. Emerging Technologies No. 18. International Standard Book No. 0-914993-16-X, Library of Congress No. 85-51133. 1986.

INTERNATIONAL TECHNOLOGY FACT SHEET

Process: Extraction of Organic Bromine From Soils Using NaOH

Type of Treatment: Chemical

Country: The Netherlands

Institution/Contact: Rulkens, Assink & Van Gemert/TNO
P.O. Box 214, 2600 AE Delft, The Netherlands
HWZ Bodemsamering
Vanadiumweg 5
3812 PX Amersfoort, The Netherlands
Tel: (033) 1 3844

Function: Extraction of organic bromine compounds from a contaminated site in Wierden using NaOH.

Description: Extraction with NaOH solution consists of the following process steps:

1. Soil pretreatment to separate large objects (e.g., stones) and reduce the size of large clods of soil (crushing and wet sieving).
2. Intimate mixing of soil with extracting agent (approximately 0.2 percent NaOH solution); the soil-to-water ratio is about 3 to 1 on a weight basis.
3. Extraction and washing of the soil with clean extracting agent in counter-current flow in two modified screw classifiers in line.
4. Dewatering of soil before redeposition. The remaining alkalinity of the soil will be largely neutralized by absorption of CO_2 from the ambient air.
5. The overflow of the first modified screw classifier is led through a settling tank for fine mineral particles dragged out from the screw classifier by the extracting liquid. The particles that settle, with diameters between approximately 35 um and 60 um (approximately 1 percent of the total soil), are collected from time to time and washed separately by mixing them with NaOH-solution.
6. Sludge forming by adding lime as coagulant and polyelectrolyte as flocculant. The sludge formed can be separated in a tiltable plate separator.

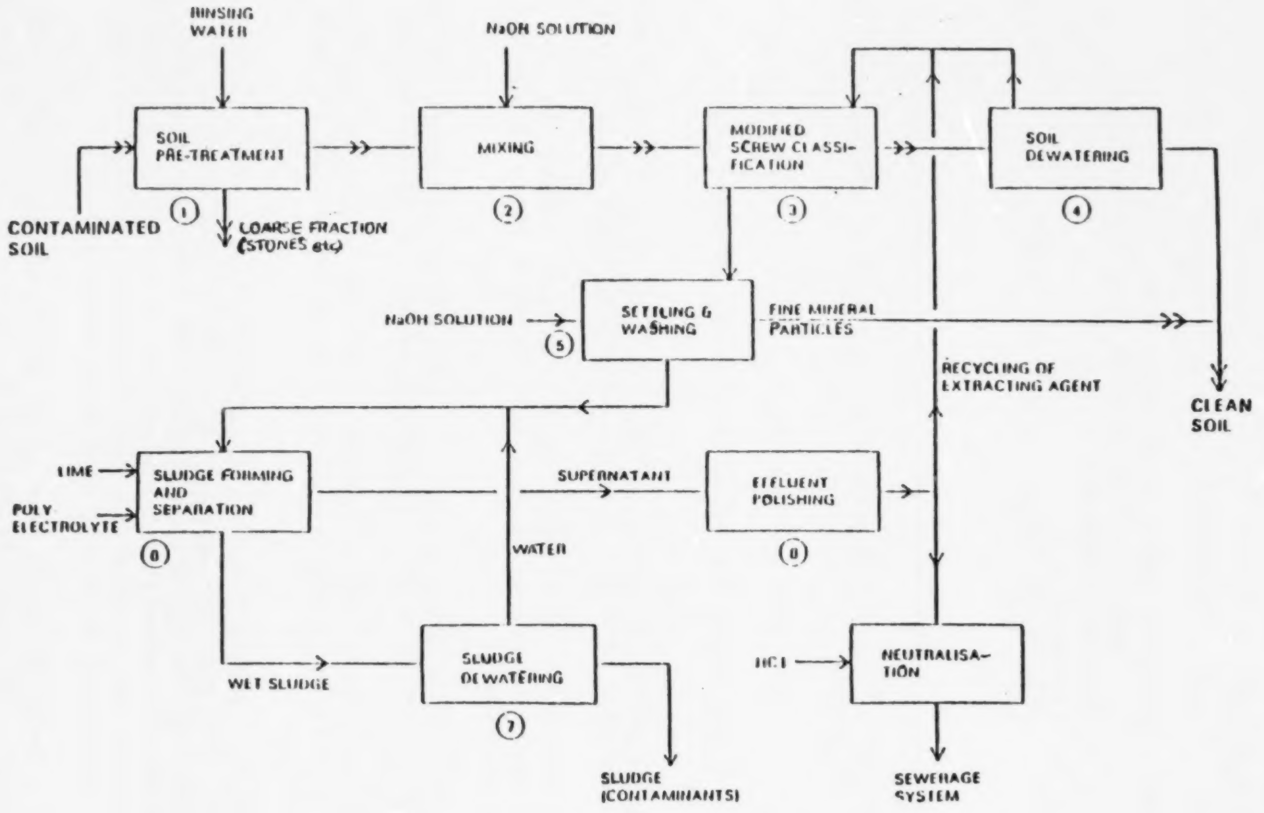

RINSING WATER
NaOH SOLUTION
CONTAMINATED SOIL
SOIL PRE-TREATMENT
①
COARSE FRACTION (STONES etc)
MIXING
②
MODIFIED SCREW CLASSIFICATION
③
SOIL DEWATERING
④
CLEAN SOIL
NaOH SOLUTION
SETTLING & WASHING
⑤
FINE MINERAL PARTICLES
RECYCLING OF EXTRACTING AGENT
LIME
POLY ELECTROLYTE
SLUDGE FORMING AND SEPARATION
⑥
SUPERNATANT
EFFLUENT POLISHING
⑧
WATER
WET SLUDGE
SLUDGE DEWATERING
⑦
SLUDGE (CONTAMINANTS)
HCl
NEUTRALISATION
SEWERAGE SYSTEM

Figure 1. Process scheme of the proposed onsite treatment installation for removing organic bromine compounds.

INTERNATIONAL TECHNOLOGY FACT SHEET (continued)

Description (cont.):

7. Dewatering of the sludge in a solid bowl centrifuge with scroll discharge.

8. Effluent polishing by deep bed filtration, activated-carbon adsorption, and finally anion exchange to remove any bromides formed by hydrolysis. The cleaned extracting agent can be recycled to the extraction process in the screw classifiers.

Performance: Experiments showed that it is possible to remove the bromine compounds from the soil down to a level of 1 mg Br/kg or less. The cleaned extracting agent contains less than approximately 0.6 mg Br/kg, the main part of which is bromide.

The waste sludge produced contains almost all the humus-like substances; very fine mineral particles (40 um) and a high concentration of bromine compounds. The amount of sludge produced is about 5 percent of the total amount of contaminated soil, owing to the high water content of the dewatered sludge (approximately 75 percent). The effluent polishing step produces small amounts of spent activated carbon (approximately 1 litre/tonne of soil), and some regeneration liquid of the anion exchanger (approximately 13 litre/tonne of soil).

Limitations: Not available.

Economics: Not provided.

Status: Experiments were conducted on a bench-scale and a pilot plant scale. An onsite treatment installation was designed based on the data.

Recommendations: A site visit and further study is recommended.

Reference: Rulkens, W.H.; Assink, J.W., and W.J. van Gemert. Detailed Description of Three Onsite Treatment Methods Developed in the Netherlands (Appendix F to Chapter 3). Undated.

INTERNATIONAL TECHNOLOGY FACT SHEET

Process: The Panel Wall as a Barrier

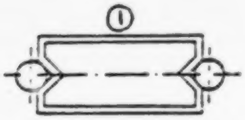
Type of Treatment: Containment

Country: The Netherlands

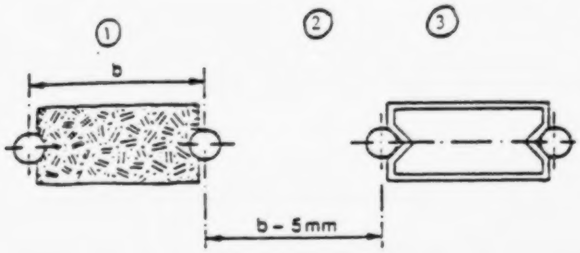
Institution/Contact: K. A. Childs
Environment Canada
Ottawa, Ontario K1A 1C8 Canada
Tel.: (819)997-2800

Function: Barrier wall.

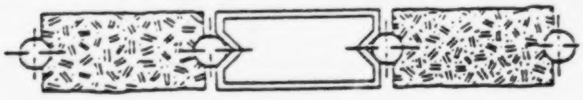
Description: An unusual panel wall was developed in the Netherlands. A description of how it is constructed follows.



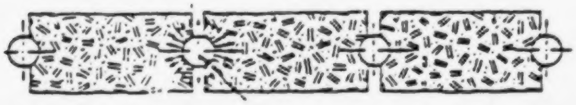
The steel form is driven between steel reinforcing tubes.



The form is withdrawn and the void filled with slurry. The form is then driven into position ③



The form is withdrawn and the void filled. The form is then driven between ① and ③ (i.e. ②.



Finally the form is withdrawn from ② the void is filled and the reinforcing tubes injected.

The maximum feasible depth of construction in this system is approximately 35 metres with a wall thickness of 0.15 to 0.30 metres.

INTERNATIONAL TECHNOLOGY FACT SHEET (continued)

Performance: This system is in the final stages of development and information on effectiveness, durability and costs are incomplete.

Limitations: Not available.

Economics: No data available.

Status: While this technology was in the final stages of development in 1983, its current status is unknown.

Recommendations: Monitor progress.

Reference: NATO/CCMS - Childs, K.A. Environment Canada. Pilot Study on Contaminated Land - Project D: Liquid Phase Management of Contaminated Land Including Horizontal & Vertical Barriers, Treatment and Modeling. December 1983.

INTERNATIONAL TECHNOLOGY FACT SHEET

Process: Boundary Film Evaporators with Carbon

Type of Treatment: Physical (with activated carbon)

Country: The Netherlands

Institution/Contact: A.B. van Luin and H. Warmer/Rijkswaterstaat
Institute for Inland Water Management
and Wastewater Treatment
P.O. Box 17
8200 AA Lelystad, The Netherlands
Tel.: 03200-70411

Function: Removal of volatile contaminants in ground water by activated carbon.

Description: Inside Boundary Film Evaporators (BFE), polluted water in batches is brought into contact with air and atomized inside a vertical vessel. In the process, a vacuum is created and the volatile compound is transferred to the air phase. Air is drawn in at the top of the vessel, and directed towards an activated carbon filter via a condenser. The water is recirculated until its condition meets the discharge requirements. The benefit of BFEs is that the air volume needed is quite small (air-water ratio is approximately 3). This is a major advantage, if the air must be treated.

Performance: On one location in the Netherlands, influent concentrations of perchloroethylene and toluene, 22 and 35 mg/L, respectively, are reduced to less than 0.05 mg/L.

Limitations: The fact that water is being treated in batches calls for a large buffer basin, as well as a compressor. Knowledge (in article) limited to perchloroethylene and toluene only.

Economics: No data available.

Status: BFEs have been tested in the field, but current status is unknown.

Recommendations: Update status with TNO. A site visit is recommended.

Reference: TNO - Assink, J.W. and W.J. van Den Brink. 1st International TNO/BMFT Conference on Contaminated Soil. November 11-15, 1985. Utrecht, The Netherlands. Published by Martinus Nijoff Publishers, Boston, MA. 1986.

INTERNATIONAL TECHNOLOGY FACT SHEET

Process: Air Stripping of Volatiles in Ground Water

Type of Treatment: Physical

Country: The Netherlands

Institution/Contact: A.B. van Luin and H. Warmer/Rijkswaterstaat
Institute for Inland Water Management
and Wastewater Treatment
P.O. Box 17
8200 AA Lelystad, the Netherlands
Tel.: 03200-70411

Function: Air stripping of volatiles in ground water.

Description: In this process, the water to be treated is fed into the top of an aeration tower. Air is injected, or drawn in at the bottom. Instead of tower aerators, plate aerators can be used. With plate aerators, the polluted water flows through a sealed reactor over a perforated plate. An underpressure is applied inside the reactor, allowing air to penetrate through the perforations in the plate, into the reactor.

Performance: With field applications of plate aerators for the removal of halogenated hydrocarbons, efficiency rates of 99.9 percent (3 nines) have been achieved, with air-water ratios of approximately 120. Reducing the tri- and tetrachloroethylene contents of the effluent to just a few ug/liter has been proven to be feasible.

Limitations: Contamination of the bed packing by flocculated iron and manganese has been seen. These components originate from the ground water. The oxygen flow causes precipitation. This contamination occurs in plate aerators as well, but the perforated plate is easy to clean.

Economics: Application of low-energy aerators can cut down on energy costs. No costs were mentioned.

Status: This technology has been applied in the field, but current status is unknown.

Recommendations: No further action. Air stripping is commonly applied in the United States.

Reference: TNO - Assink, J.W., and W.J. van Den Brink. 1st International TNO/BMFT Conference on Contaminated Soil. November 11-15, 1985, Utrecht, The Netherlands. Published by Martinus Nijoff Publishers, Boston, MA. 1986.

INTERNATIONAL TECHNOLOGY FACT SHEET

Process: Microfiltration of Zinc-Contaminated Ground Water

Type of Treatment: Physical

Country: The Netherlands

Institution/Contact: A.B. van Luin and H. Warmer/Rijkswaterstaat
Institute for Inland Water Management
and Wastewater Treatment
P.O. Box 17
8200 AA Lelystad, the Netherlands
Tel.: 03200-70411

Function: Microfiltration of zinc-contaminated ground water.

Description: Microfiltration, a membrane filtration technique, has been applied to the treatment of zinc-contaminated ground water. Zinc is separated as zinc hydroxide flocs produced through the action of caustic soda and the iron in the ground water. These flocs are removed from the water phase through asymmetric microfiltration membranes. At a flow rate of 15 to 20 m^3 of ground water/hour, 36 m^2 of membrane area is required. The concentrate is further thickened and carried off.

Performance: The permeate contains less than 100 ug/L zinc.

INTERNATIONAL TECHNOLOGY FACT SHEET (continued)

Limitations: Not available.

Economics: No data available.

Status: In 1985 this technique was applied in the field to zinc-contaminated ground water, but current status is unknown.

Recommendations: No further action recommended. Microfiltration is commonly applied in the United States.

Reference: TNO - Assink, J.W., and W.J. van Den Brink. 1st International TNO/BMFT Conference on Contaminated Soil. November 11-15, 1985, Utrecht, The Netherlands. Published by Martinus Nijoff Publishers, Boston, MA. 1986.

INTERNATIONAL TECHNOLOGY FACT SHEET

Process: Decontamination of Excavated Soil by Composting

Type of Treatment: Biological

Country: The Netherlands

Institution/Contact:

Ir. J. F. de Kreuk
TNO Hoofdgroep Maatschappelijke Technologie
P.O. Box 217
2600 AE Delft
Tel.: 015-569330

*J.J. Gaastra
Joh. Mourik & Co.
Holding B.V.
P.O. Box 2
2694 ZG Groot Ammers
The Netherlands

Function: Soil cleaning.

Description: A composting-like technique was used (apart from pilot-plant experiments) by Mourik for decontaminating 1,000 tons of a loamy soil contaminated with gasoline. The soil, containing about 1,500 mg/kg of gasoline, was mixed with a fertilizer and placed in a basin equipped with facilities for air injection into the soil. The soil was covered with a plastic foil. After passage through the soil, the air was passed through a compost filter for biological degradation of any volatile compounds it might have taken up from the soil. The temperature was maintained at 22 to 25°C.

Performance: After 7 or 8 weeks, the oil concentration in the soil had fallen to 350 to 500 mg/kg. No measurements of microbial activity were carried out.

INTERNATIONAL TECHNOLOGY FACT SHEET (continued)

Limitations: Not available.

Economics: No data available.

Status: Pilot-plant experiments have been performed on this technology and it was employed to remediate 1000 tons of loamy soil in the field.

Recommendations: Update status including economics and limitations.

Reference: TNO - Assink, J.W. and W.J. van Den Brink. 1st International TNO/BMFT Conference on Contaminated Soil. November 11-15, 1985. Utrecht, The Netherlands. Published by Martinus Nijoff Publishers, Boston, MA. 1986.

INTERNATIONAL TECHNOLOGY FACT SHEET

Process: Specialized Microbial Degradation of Excavated Soil

Type of Treatment: Biological

Country: The Netherlands

Institution/Contact: Ir. J. F. De Kreuk
TNO Hoofdgroep Maatschappelijke
Technologie
P.O. Box 217
2600 AE Delft, the Netherlands
Tel.: 015-569330

Function: Specialized micro-organisms for high-rate biotreaters.

Description: The Groningen Biotechnology Centre of Groningen University is engaged in a search for specialized microorganisms capable of degrading specific chemicals such as the lower halogenated alkanes. Together, with TNO, the institute will investigate the feasibility using such organisms in high rate biotreaters affording high rates of biodegradation. Several microorganisms exhibiting considerable ability to degrade chlorinated C_1 to C_6 hydrocarbons have already been isolated (Janssen, 1985).*

*Jansen, D.B., A. Scheper, B. Witholt: Degradation of halogenated aliphatic compounds by "Xanthobacter antotrophicus" G J 10, Appl. Env. Microbiology 49: 673-677, 1985.

Performance: Data not available.

INTERNATIONAL TECHNOLOGY FACT SHEET (continued)

Limitations: Data on limitations are not yet available due to the early status and small scale of the experiments.

Economics: No data available.

Status: Experiments are on a laboratory scale.

Recommendations: Update progress and status of investigations at the Groningen Biotechnology Centre of Groningen University.

Reference: TNO - Assink, J.W. and W.J. van Den Brink. 1st International TNO/BMFT Conference on Contaminated Soil. November 11-15, 1985. Utrecht, The Netherlands. Published by Martinus Nijoff Publishers, Boston, MA. 1986.

INTERNATIONAL TECHNOLOGY FACT SHEET

Process: In Situ Steam Stripping of Soils

Type of Treatment: Thermal

Country: The Netherlands

Institution/Contact: Mr. C. Jonker/Heijmans Milieutechniek B.V.
P.O. Box 2
5240 BB Rosmalen, the Netherlands
Tel.: 04192-89111

Function: Treatment of contaminated soil in situ.

Description: The treatment of soil by the method of steam stripping is founded on the principle that the contamination present in the ground, expecially the relatively easily vaporizing hydrocarbons, are made volatile by acceleration through the introduction of steam. Subsequently, the vaporized contaminated materials, in conjection with an excess of steam, are driven out of the soil. In situ stream stripping was further developed, after obtaining the licence, and made virtually operational by Heijmans Millieutechniek B.V. Steam with a temperature of between 130 and 180°C is injected into the soil at a number of points. At another point, near the injection point, a mixture of steam and gaseous materials is, under a specific pressure, absorbed to the soil.

The steam serves a dual purpose in this respect:

- vaporizes the contaminated materials; and
- becomes the medium of transport for the gaseous materials.

By maintaining a specific underpressure at the absorption point, a lowering of the boiling point of the hydrocarbons will occur, causing in combination with the greater pressure-gradient an acceleration of the vaporizing and removal process, which will be beneficial to the method's effectiveness. The mixture of steam and gaseous hydrocarbons is subsequently condensated in a condensor. After the removal of a floating layer of oily components, if present, the watery condensate is further treated, e.g., by the method of filtration, air stripping, and/or active carbon adsorption. Proven techniques in the field of water purification are used in this respect (see Figure 1).

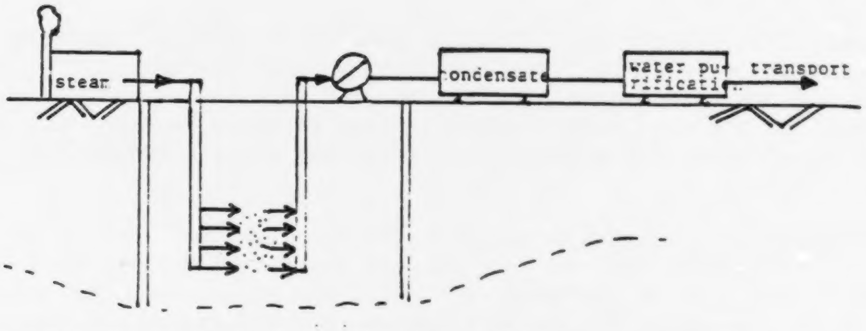


Figure 1. Principle diagram of in situ steam stripping.

Applicability of the Method: The system lends itself to the treating of all types of vaporizable material such as aromatic hydrocarbons, polycyclic aromatic hydrocarbons, mineral oil and, especially, halogenated hydrocarbons with boiling points of between 100 and 250°C. The method produces the best results in sand-containing soils. Dislocation layers in the form of bog or loam/clay need not present difficulties in view of the method of injection and absorption to be discussed hereafter. The introduction may be referred to in respect of ground water treatment and specific applications below and alongside buildings.

Performance: In August 1983, in Utrecht's Griftpark, a number of tests were executed in which a vacuum bell of 2 x 2 m^2, with four lances for steam injection, was placed on the land level. The soil was of a layered composition, i.e., sand, layers of slags, layer of clay and bog with more sand underneath. Sampling before and after the tests rendered the following global picture in relation to the degree of removal:

- Benzene, toluene, ethyl benzene, xylene (BTEX) varying from 20 percent (layer of clay) to 99.5 percent (sand);
- Naphthalene, varying from 60 percent (clay) to 99.9 percent (sand);
- Remaining polycyclic aromatic hydrocarbons: varying from 35 percent (bog) to 97 percent (sand); and
- Phenol, varying from 20 percent to 80 percent (sand and clay).

It must be stated that during the treatment the conditions were not the most favorable, and that the test was not prolonged enough to attain an insight into all process parameters.

Performance (cont.):

In February 1985, on the site formerly used by Broomchemie, Wierden, a number of tests were carried out in which the soil was injected with steam to a depth of 4.5 meters below the land level by use of a vacuum bell of 2 x 2 m^2 with four lances for steam injection. The soil was made up of sand, the ground water level was about 5 meters below land level.

The contamination consisted or organic bromide compounds varying in concentration between 7700 to 3 mg/kg EOBr dry material. On the basis of sampling in the part of the soil over which the vacuum bell had stood, and in which the lances for steam injection had penetrated, it was established that the maximal concentration of 7700 mg/kg had been reduced to 220 mg/kg (at a depth of 2 meters below land level), correlating with a removal percentage of 97. Further analysis, however, showed that the organic bromide had for a very considerable part been converted into inorganic bromide, and was only for a minor part present in the condensate, a condition that was caused by the relatively weak bond of the bromide ion to the carbon chain.

In November 1984, in the grounds of a former gasworks in Mannheim, a series of tests was executed employing a system of injection and absorption points (Figure 2), as well as a vacuum bell (Figure 3). The soil consisted of rough, sandy material in which between 1.8 and 2.6 meters below land level a contaminated layer had originated. The contaminations constituted: benzene (55 mg/kg), toluene (15 mg/kg), xylene and ethyl benzene (2 to 4 mg/kg), and phenol (30 mg/kg). After steam stripping, all contaminations were found to be below detection limit.

Overall, however, steam stripper performance has been poor.

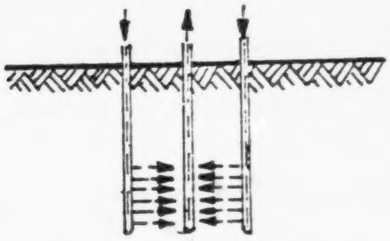


Figure 2. Parcel of lances horizontal transport of steam.

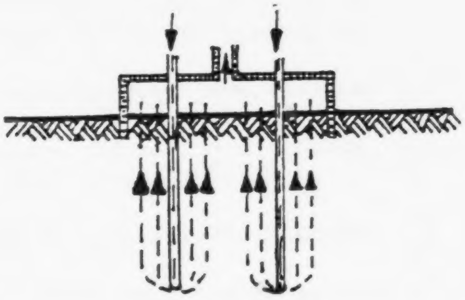


Figure 3. Vacuum bell with four lances vertical transport of steam.

Limitations: Effective only on specific contaminants (i.e., volatile hydrocarbons). More limitations will probably be discovered after construction of pilot plant.

Economics: The cost price of in situ treatment is very much dependent on factors such as soil, nature and concentrations of contaminations, period of time, etc. For the moment an indication of Dfl 50 - Dfl 150, for each m^3 can be given. On comparison with other methods of treatment of contaminated soils it must be realized that in the case of in situ treatment, no costs of excavating, transport and storage are involved. In addition to this, steam stripping, by its method of condensate treatment, is a thermic method which does not cause environmental nuisance.

Status: Trial cleanings performed; the Technological University, Eindhoven and TNO, Apeldoorn were commissioned to develop on a laboratory and pilot-plant scale, a mobile steam stripping plant, but due to the poor performance of the steam stripper, the study has been halted.

Recommendations: A site visit was initially pursued. However, based on poor performance found from initial contacts, no further study is recommended.

Reference: TNO - Assink, J.W. and W.J. van Den Brink. 1st International TNO/BMFT Conference on Contaminated Soil. November 11-15, 1985. Utrecht, The Netherlands. Published by Martinus Nijoff Publishers, Boston, MA. 1986.

INTERNATIONAL TECHNOLOGY FACT SHEET

Title: Steam Stripping of Excavated Soil

Type of Treatment: Thermal

Country: The Netherlands

Institution/Contact:

Mr. Jan Willem Assink
TNO
P.O. Box 342
7300 AH Apeldoorn,
The Netherlands
055-773344

Mr. Jonker
Heijmans Milieutechniek BV
P.O. Box 2
5240 BB Rosmalen,
The Netherlands
04192-89111

Function: Treatment of contaminated soil that has been excavated.

Description: Steam stripping of soil which has been excavated with onsite capability. For a description of the process, refer to the Fact Sheet "In Situ Steam Stripping of Soils".

Performance: Expected to be able to treat most types of volatile contaminants in soil. Bench-scale performance was reported to be unsatisfactory, but results have not been formally published.

Limitations: None available.

Economics: Costs appear to be comparable to other current soil extraction techniques: 100 to 150 Dutch Guilders/ton.

Status: Bench-scale, only 50 to 100 kg of contaminated soil have been treated in experiments. It is reported that a pilot-scale system will not be built due to poor performance of the bench-scale system.

Recommendations: Information on this technology has not been published; it is proprietary information. No follow up is recommended.

References: Assink, Jan W., conversation with J. Hyman on November 9, 1987.

Jonker, C., conversation with J. Hyman on January 28, 1988.

INTERNATIONAL TECHNOLOGY FACT SHEET

Process: DHV Pelletizing Process for Metal-Plating Sludge

Type of Treatment: Physical/Chemical

Country: The Netherlands

Institution/Contact: Mr. J. Koning and Mr. W.F. Kooper
DHV Consulting Engineers
P.O. Box 85
3800 AB Amersfoort, The Netherlands
Tel.: 033-689111

Function: A pelletizing process to eliminate sludge production.

Description: DHV Consulting Engineers has developed a pelletizing process that eliminates the sludge-disposal problem of precipitation methods. Instead of sludge, pure granular metal-carbonate crystals are produced that can be reused as feed for new electroplating baths. Key to the technology is a cylindrical pellet reactor partially filled with suitable seed material, such as sand. The fluid velocity in the reactor is so high (40 to 100 m/h) that the grains are kept in suspension, preventing cementation. A carbonate solution, added to the reactor along with the wastewater, causes the metal carbonates to crystallize on the seed material. The reaction takes place very quickly, so that only a small reactor volume is needed.

Performance: A 3 m-high, 20 cm diameter reactor can treat a flow of 1.2 m^3/h.

Limitations: Not provided.

Economics: Investment costs are estimated at $4,000 to $20,000 for plants treating 0.5 to 5.0 m^3/h.

Status: Unknown.

Recommendations: Seems to have limited Superfund uses. No further action recommended.

Reference: Chemical Engineering (Int. Ed.), 2 March 1987, 94 (3), 9-10. - (News Item).

INTERNATIONAL TECHNOLOGY FACT SHEET

Title: Washing of Cadmium-Polluted Soils

Type of Treatment: Physical

Country: The Netherlands

Institution/Contact:
L.G.C. M. Urlings
TAUW Infra Consult B.V.
P.O. Box 479
7400 AL Deventer, the Netherlands
Tel: 05700-999-11

J.J. Gaastra
Maurik B.V.
P.O. Box 2
2694 ZG Groot Ammers, the Netherlands

Function: In situ remediation of cadmium-polluted soil.

Description: A photopaper producing plant in Utrecht disposed Cd-containing wastewater into infiltration ponds. Periodical flooding of these ponds caused the adjacent soil to become polluted with a total Cd-content of about 725 kg and concentrations over 20 mg Cd/kg soil.

The polluted sandy soil is to be cleaned by percolation with acidified water (pH = 3.5). The percolate will be pumped into a ground water cleaning installation and then re-infiltrated. The acidic water will be recirculated until the Cd-concentration in the percolate reaches a constant low value. Batch experiments with pollutant soil were carried out to study various aspects of the technique. Addition of 10-3 mol HCl to the ground water enhanced desorption of the Cd from the soil. A cross-section of the infiltration and withdrawal system is shown in Figure 1. The three appropriate techniques for removing Cd from the wastewater were surveyed:

precipitation/flocculation;
biosorption; and
sorption by resins.

Precipitatiion/flocculation was not chosen because it tends to increase the salt content in the recirculated water. This was undesirable since the site was in the vicinity of a ground water drinking station. Biosorption techniques were impractical on this scale. Sorption by resins was selected and the resin GT-73 was chosen based on its performance in batch experiments. The full-scale in situ water treatment plant is shown in Figure 2.

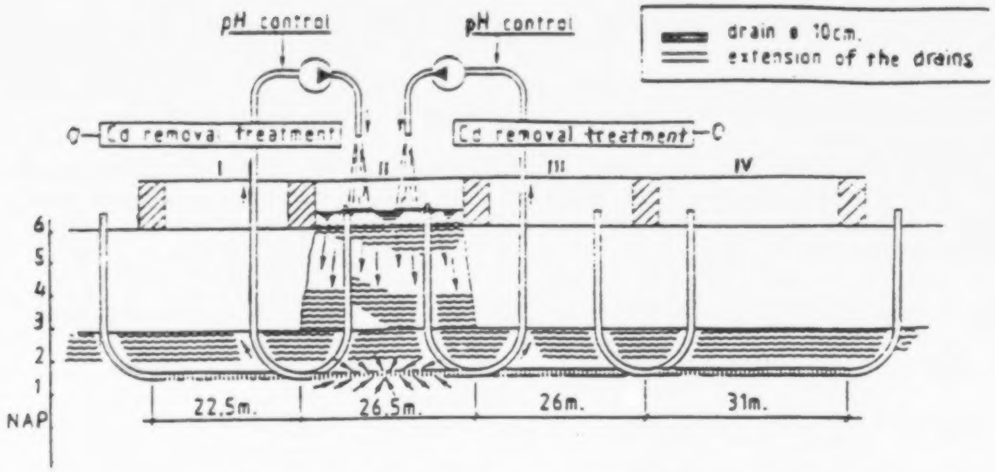

pH control
pH control
drain ø 10cm.
extension of the drains
Cd removal treatment
Cd removal treatment
I
II
III
IV
6
5
4
3
2
1
NAP
22.5m.
26.5m.
26m.
31m.

Figure 1. Cross-section of the infiltration and withdrawal system.

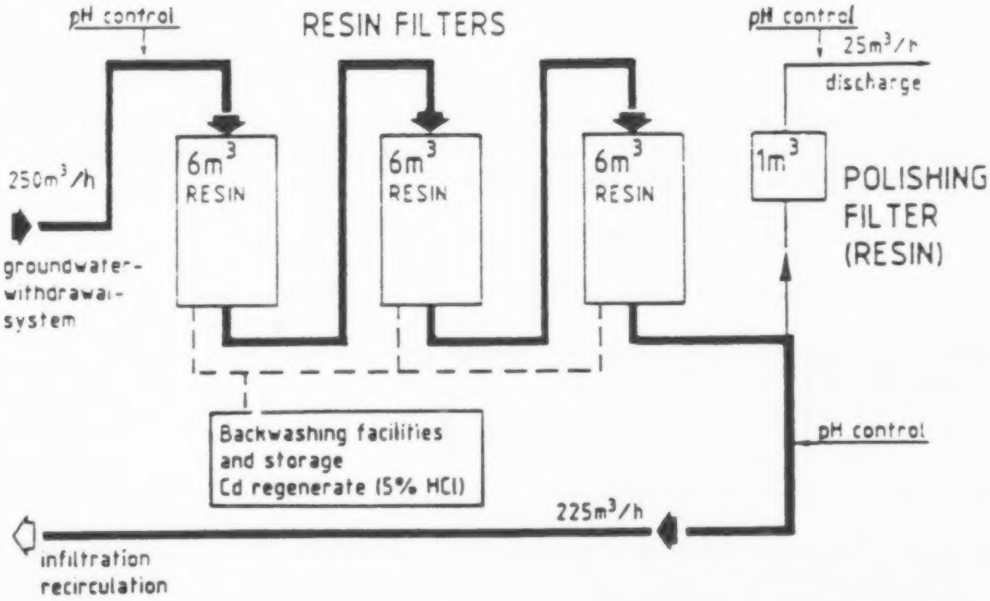

pH control
RESIN FILTERS
pH control
25m³/h
discharge
250m³/h
6m³ RESIN
6m³ RESIN
6m³ RESIN
1m³
POLISHING FILTER (RESIN)
groundwater-withdrawal-system
Backwashing facilities and storage Cd regenerate (5% HCl)
pH control
225m³/h
infiltration recirculation

Figure 2. Water treatment plant.

Performance: The time for treatment is predicted to be 25-30 days for each of the six compartments of 1000 m^2 each. the capacity of the ground water treament installation was limited to 250 m^3/hr so it was divided into compartments.

As of February 1988, treatment was going very well. The ion exchange resin was showing a very good performance, having only lost a few percents of efficiency after several regenerations with a strong acid.

Limitations: The hydraulic properties of the soil in the field were different from the initial measurements taken on the episoil.

Economics: Urlings, et al. explains "The benefit can be high as 25 percent of the total cost of 4 million guilders".

Status: In situ remedial action began in the summer of 1987 and will last approximately one year. Preliminary evaluation and recommendations are expected by the end of January 1988.

Recommendations: Further study is needed and therefore, a site visit recommended.

Reference: Urlings, L.G.C.M.; Blonk, A.T.; Woelders, J.A.; and P.R. Massink. "In-situ Remedial Action of Cadmium-Polluted Soil", Second European Conference on Environmental Technology. Amsterdam, The Netherlands, 22-26 June 1987.

INTERNATIONAL TECHNOLOGY FACT SHEET

Process: Anodic Oxidation of Cyanide

Type of Treatment: Chemical

Country: Sweden

Institution/Contact: Nils-Erik Sodermark
Koping, Sweden

Function: Removal of cyanides from electroplating baths at concentrations of 10 to 20 g of cyanide/liter of solution by anodic oxidation.

Description: The process is carried out while the cyanide solution is being stirred by a propeller. Intense agitation draws air into the electrolyte to shorten the electrolysis time and prevent corrosion of the anode. Process chemistry details include halide concentration of about twice the cyanide content; current density of about 3 to 3.5 A/dm^2; and pH adjusted to about 11 with NaOH.

Performance: A test was conducted using 300 liters of liquid waste containing about 2.5 g of cyanide ion/liter of solution. Process conditions included: propeller speed of 900 rpm; pH of 11; 1% NaCl by weight; current density of 3 to 3.5 A/dm^2; and a voltage of 16 passed through the electrolyzer. These process conditions achieved complete oxidation within 15 minutes.

INTERNATIONAL TECHNOLOGY FACT SHEET (continued)

Limitations: Not provided.

Economics: No cost data are available.

Status: The process was patented in the U.S. (4,417,963) by Joumo Janne of Sweden.

Recommendations: Limited Superfund applications. No further study recommended.

Reference: Technical Insights. New Methods for Degrading/Detoxifying Chemical Wastes. Emerging Technologies No. 18. International Standard Book No. 0-914993-16-X, Library of Congress No. 85-51133. 1986.

INTERNATIONAL TECHNOLOGY FACT SHEET

Process: Heavy Metal Removal Via Sulfate-Reducing Bacteria

Type of Treatment: Biological

Country: Sweden

Institution/Contact:
Rolf O. Hallberg
Tyreso, Sweden

Vyrmetoder AB
Taby, Sweden

Function: Process removes heavy metals from wastewaters containing sulfate ions by means of sulfate-reducing bacteria.

Description: The bacteria can be any of the known sulfate reducers, including Desulfovibrio and Desulfotomaculum. The bacteria reduce the sulfate to sulfides, producing hydrogen sulfide gas, and leaving the heavy metals to precipitate out as sulfides. Two vessels are used, one for culturing the bacteria in a nutrient and the wastewater, and the other for precipitation. Holding time in the culture vessel may be 10 to 40 hours. An aqueous solution of hydrogen sulfide produced in the culturing vessel is fed continuously into the precipitation vessel along with the remainder of the wastewater. The resulting precipitate is flocky and settles easily.

Performance: Wastewater with a sulfate ion content of about 600 mg/L, copper content of 10 mg/L, zinc of ~~abou~~t 600 mg/L, and iron about 500 mg/L was treated by this process. Unfiltered water from the precipitation vessel contained up to 0.1 mg/L of copper, 0.1 mg/L of zinc, hydrogen sulfide of about 10 mg/L, and 10 mg/L of iron. Iron content could be reduced to zero by adjusting the pH in the vessel.

INTERNATIONAL TECHNOLOGY FACT SHEET (continued)

Limitations: No information available.

Economics: No information available.

Status: U.S. Patent 4,354,937 awarded to Rolf Hallberg of Tyreso, Sweden, has been assigned to Vyrmztodec AB, Taby, Sweden.

Thiobacillus ferrooxidans has been used in the laboratory to recover gold from low-grade ores. Mine tailings, incinerator ash, and electroplating wastes are other areas of application for the process. Eric Livesey-Goldblatt has been working on the process for GENCOR Laboratories, a South African firm. He has formed a consulting company, Biomet, to screen and develop new strains. A Canadian company, Bio Logicals, has North American rights.

Two Japanese firms are also exploring T. Ferrooxidans for wastewater treatment. Dow Mining Co., Ltd., and Nippon Electric Co., Ltd., are pilot testing a 20 mL/min process for the Metal Mining Agency of Japan. This process and other processes using bacteria for the selective removal of heavy metals.

Recommendations: Limited Superfund applications. No further action recommended.

Reference: Technical Insights. New Methods for Degrading/Detoxifying Chemical Wastes. Emerging Technologies No. 18. International Standard Book No. 0-914993-16-X, Library of Congress No. 85-51133. 1986.

INTERNATIONAL TECHNOLOGY FACT SHEET

Process: SAKAB Norrtorp Rotary Kiln Incinerator

Type of Treatment: Thermal

Country: Sweden

Institution/Contact: Clyde J. Dial
Alternative Technologies Div., EPA

Lars Ljung
Teknist Chef
SAKAB
Norrtorp, 69200 Kumla
Tel.: 019-77200

Function: Incineration at Sweden's central hazardous waste treatment facility, SAKAB.

Description: The incineration unit is designed to handle about 33,000 tons of wastes/year. The waste is fed through the front end of a rotary kiln through a burner or lances for pumpable wastes, or through input locks for drums and solid wastes. The primary air intake is also located at the front of the kiln. The rotary kiln is 12 meters long and has an inside diameter of 4-1/2 meters. The kiln and post-combustion chamber are lined with refractory brick. The temperature of the kiln varies from 1,000 to 1,300°C. They attempt to slag all drums that enter the kiln. During a visit, there was evidence that this was not being achieved.

The flue gases from the kiln are supplemented with additional air in an afterburner whose temperature is controlled by using oil. The flue gases then pass to an exhaust gas boiler where the heat contained in the exhaust gas is utilized for the generation of steam. The steam is then to generate electricity for heating the plant and as a source of heat for the local authority's district heating network. After the flue gases pass through the steam generator, they are cleaned in a scrubber and then pass through an electrostatic precipitator. Lime is added in solution and atomized by a rotating spreader disk. Hydrogen chloride, hydrogen fluoride, and sulfur dioxide/trioxide contained in the hot gases react with the lime solution as the water evaporates due to the heat of the flue gases. The dry reaction product is removed at the bottom of the reaction tower and the electrostatic precipitator. The clean flue gases are exhausted through a 60-meter high stack.

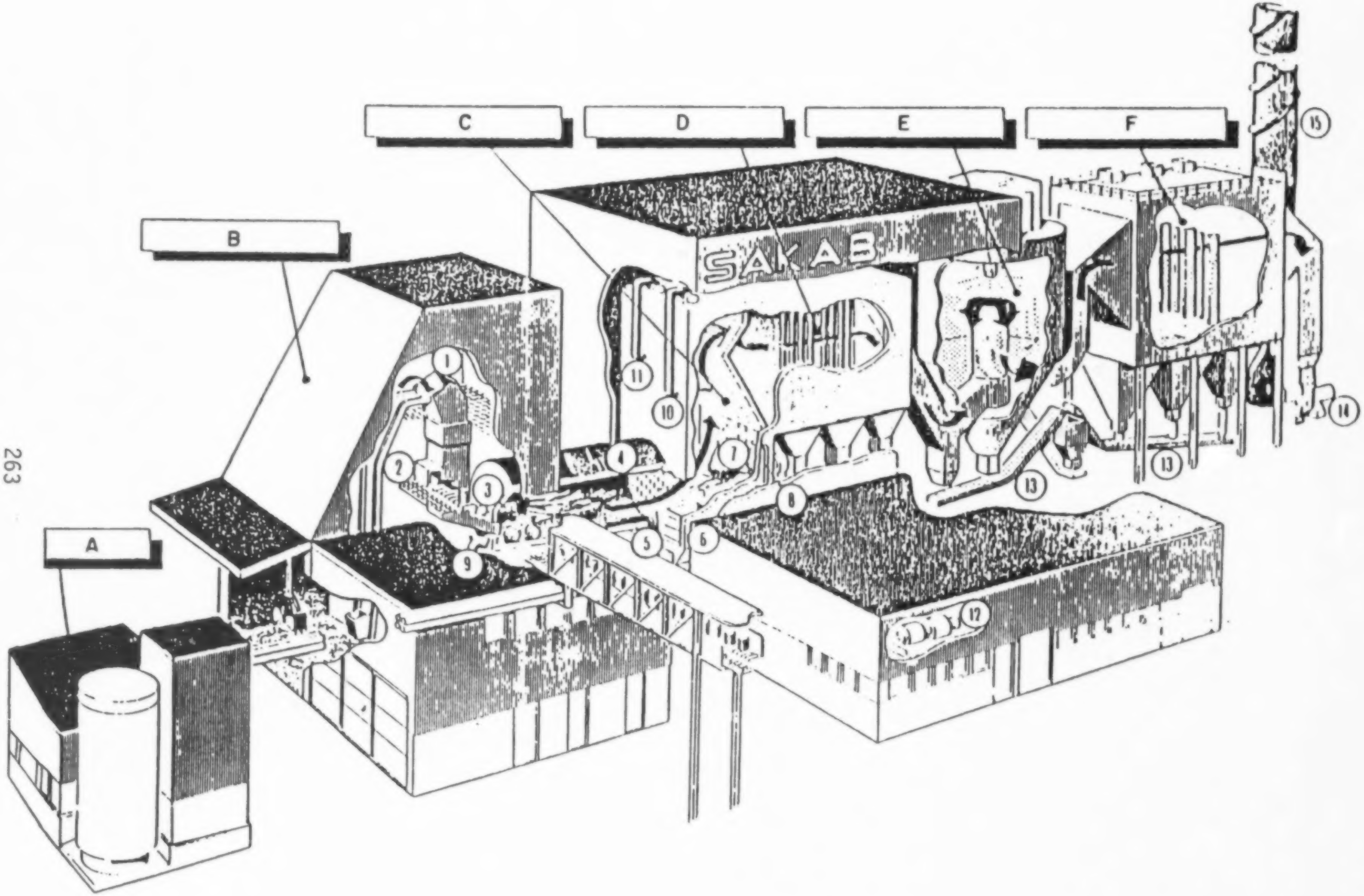
Description (cont.):

All these types of waste may be incinerated at SAKAB:

- Waste containing oil;
- Solvent waste;
- Paint or varnish waste;
- Adhesive waste;
- Waste containing organic substances contaminated by heavy metals;
- Waste containing PCB;
- Pesticide waste; and
- Other chemicals and byproducts from the manufacture of plastics, pharmaceuticals, and chemicals.

Performance: The standards for the plant's flue gas are as follows (monthly values): dust, 35 mg/m^3; HCl, 35 mg/m^3; and HF, 5 mg/m^3. All are corrected to 10 percent carbon dioxide. This plant's standards are such that not more than 50 mg of organic material can be emitted in the flue gas per kilogram of completely dry waste feed. A schematic of the plant is shown in Figure 1.

Limitations: Not provided.


A
B
C
D
E
F
SAKAB
1
2
3
4
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13
14
15

Figure 1. A diagram of the SAKAB rotary kiln incinerator.
(see key on following page)

KEY to FIGURE 1

A - District heating station
B - Input building
C - Post-combustion chamber
D - Exhaust gas boiler
E - Flue gas cleaning
F - Electrostatic precipitator

1 Solid waste input
2 Drum input
3 Pumpable waste input
4 Rotary kiln
5 Slag smelter
6 Slag quenching bath
7 Oil burner
8 Contaminated water input
9 Primary air
10 Secondary air
11 Tertiary air
12 Back-pressure turbine
13 Dust discharge
14 Flue gas fan
15 Chimney stack

INTERNATIONAL TECHNOLOGY FACT SHEET (continued)

Economics: A total of 250 million Swedish Kronor has been invested in SAKAB Norrtorp, which also provides the Kumla Local Authority with district heating.

Status: SAKAB has been in service since 1983.

Recommendations: Although this unit does have merit, it is difficult to determine if it is new technology. No further action is recommended.

Reference: Dial, Clyde J. Director of U.S. EPA HWERL Alternative Technologies Division. Trip Report - Stockholm, Zurich, Ebenhausen (FRG) and Fawley (U.K.). April 14-27, 1985.

INTERNATIONAL TECHNOLOGY FACT SHEET

Process: Electro-reclamation of Chlorine and Sodium From Soils

Type of Treatment: Physical/Chemical

Country: United Kingdom

Institution/Contact: R. Hamnett
University of Manchester
Master's Thesis (under contract of: Corrosion and Protection Centre Industrial Services (CAPCIS))

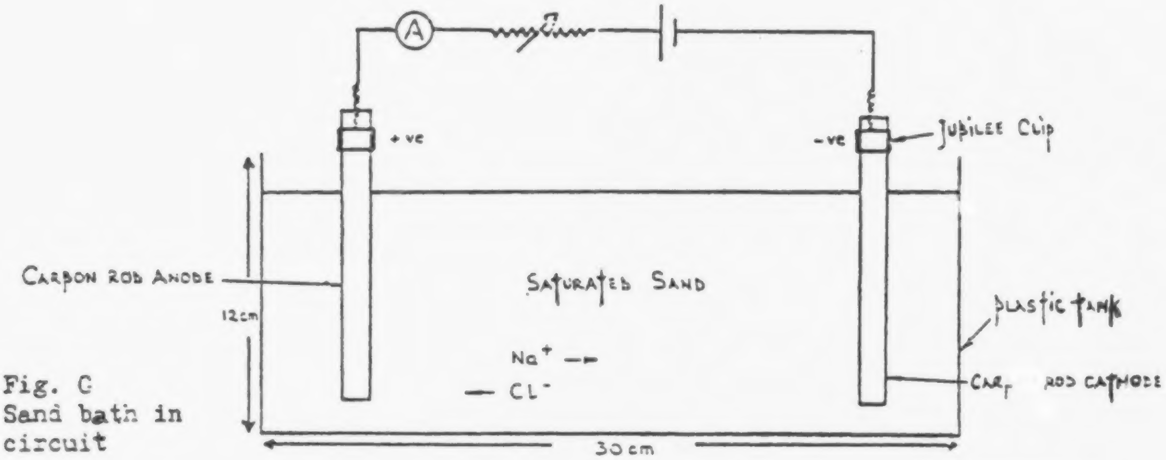
Function:
1. Abstraction of toxic elements from the soil.
2. An aid to the permeation of grouting or leaching materials in soils of low permeability.

Description: Electro-osmosis as a civil engineering technique was originally developed as a method for dewatering low permeability active clay soils. The principle is that if an electric potential is applied to a saturated porous material, electrolyte will flow from the anode to the cathode. The movement of cations towards the cathode is accelerated by the movement of water in this direction. If moisture content is maintained in the vicinity of the anode as an electrolyte, anions will move in the other direction. Some electrode configurations are shown in Figure 1.

Performance: Experiments demonstrated the feasibility of removing both chloride and sodium ions from soil using a reasonably moderate current.

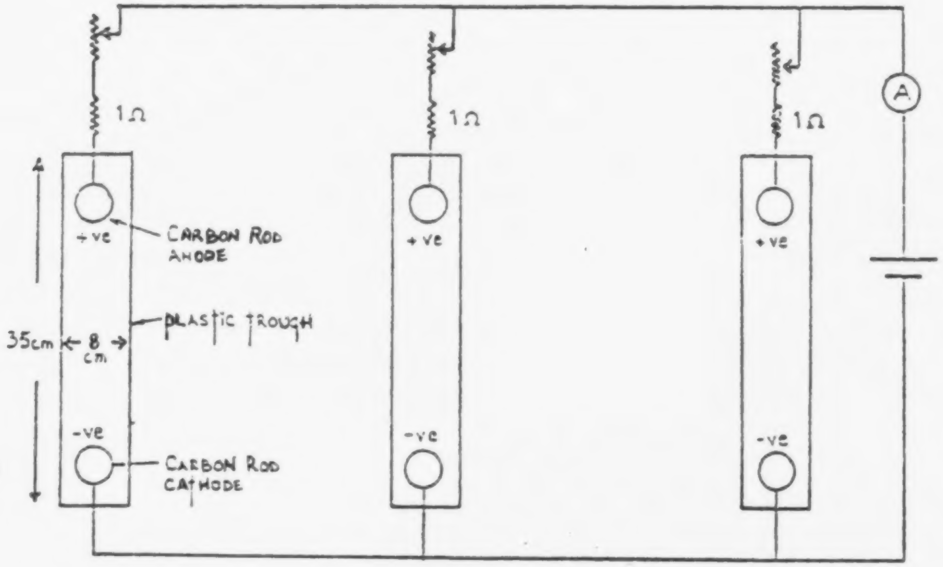
Limitations: There seems likely to be difficulties regarding its application to earth containing a range of contaminants, some of which may be strongly bound chemically to the soil. Also, physical breakdown of the anode occurs due to electrolytic reactions; new anodes must be repeatedly substituted. Soil must be wet since water provides a transporting medium for ions. When dissociating Cl from the soil, there is a significant evolution of chlorine gas at the anode.

Economics: Cost will depend on materials and the cost of electricity at the site.



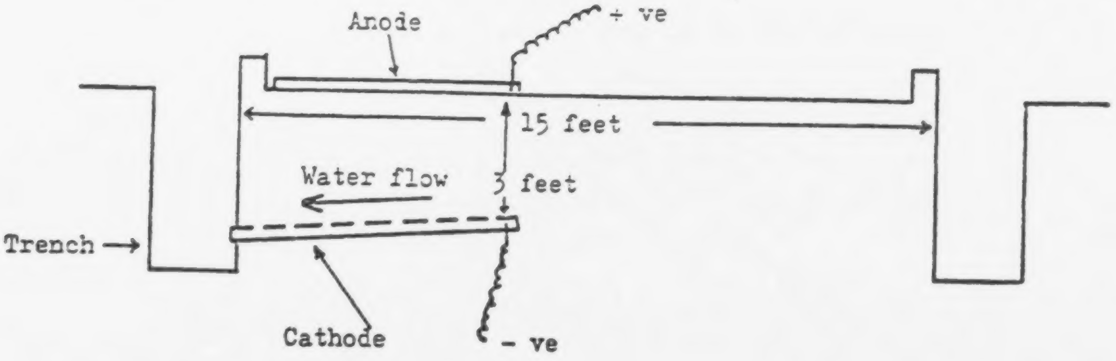
A
+ve
-ve
JUBILEE CLIP
CARBON ROD ANODE
SATURATED SAND
PLASTIC TANK
12cm
Na^+ →
← CL^-
CAR ROD CATHODE
30 cm

Fig. C
Sand bath in
circuit



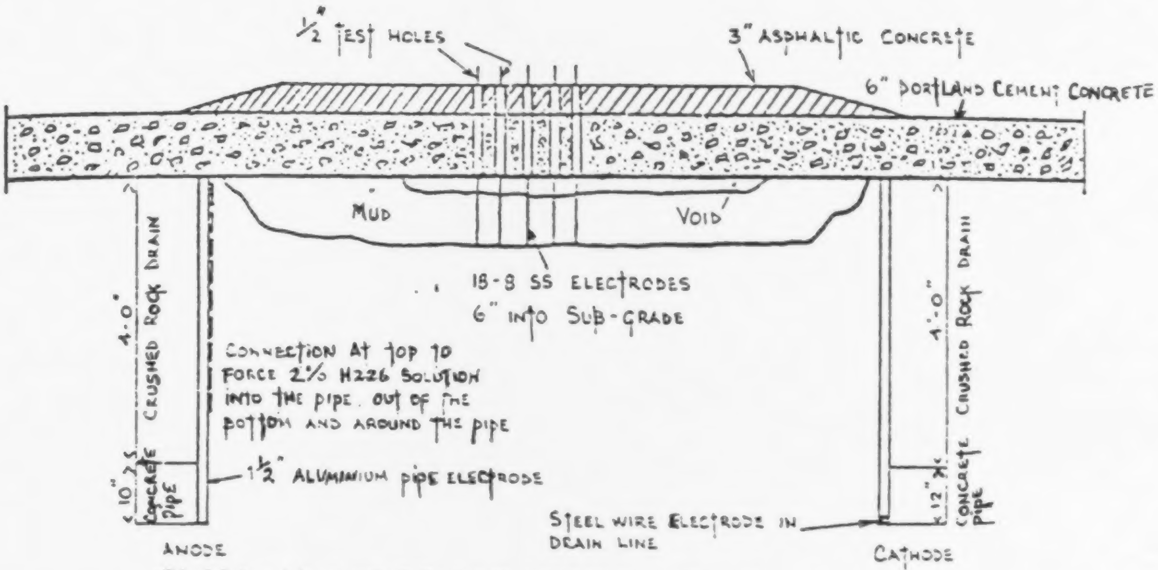
1Ω
1Ω
1Ω
A
+ve
+ve
+ve
CARBON ROD ANODE
PLASTIC TROUGH
35cm
8 cm
-ve
-ve
-ve
CARBON ROD CATHODE

Fig. B
Sand troughs
in circuit



Anode
+ ve
15 feet
Water flow
3 feet
Trench
Cathode
- ve

Figure 1. Electrode configurations.


½" TEST HOLES
3" ASPHALTIC CONCRETE
6" PORTLAND CEMENT CONCRETE
MUD
VOID
18-8 SS ELECTRODES
6" INTO SUB-GRADE
4'-0"
CRUSHED ROCK DRAIN
CONNECTION AT TOP TO
FORCE 2% H226 SOLUTION
INTO THE PIPE. OUT OF THE
BOTTOM AND AROUND THE PIPE
10"
CONCRETE PIPE
1½" ALUMINIUM PIPE ELECTRODE
4'-0"
CRUSHED ROCK DRAIN
12"
CONCRETE PIPE
STEEL WIRE ELECTRODE IN
DRAIN LINE
ANODE
CATHODE

Stablisation of Sub-Soil Beneath a Runway

Figure 1. (cont.)

Status: Laboratory studies on model systems have been carried out with some promising results. A field experiment was done in 1982 by R. Hamnet for Building Research Establishment (BRE).

Field experiments need to be performed on an actual site to examine the effects of the soil electrochemistry and the competing movement of the other cations and anions on the diffusion of the ion(s) in question. This seems to be a potentially useful technique, but there are many variables to be taken into account before the electro-osmosis and electrolytic processes are understood:

- Temperature;
- Moisture content;
- Soil type;
- Voltage;
- Current;
- Salinity;
- pH; and
- Electrode configuration.

Under the influence of an electric current, other electrochemical effects besides electro-osmosis and electrolysis need to be evaluated before ion behavior can be understood:

- Ion exchange;
- Ion diffusion;
- The generation of secondary minerals;
- The generation of pH gradients.
- Mineral decomposition;
- Precipitation of secondary minerals;
- Oxidation; and
- Reduction.

Recommendations: No further action recommended.

Reference: Hamnett, R., and T.P. Dip. A Study of the Processes Involved in the Electro-Reclamation of Contaminated Soils. Master of Science Degree Thesis. Pollution Research Unit, University of Manchester. October 1980.

INTERNATIONAL TECHNOLOGY FACT SHEET

Process: Maguire VO_2 Aeration System for Biological Enhancement

Type of Treatment: Biological

Country: United Kingdom

Institution/Contact: Tom Maguire & Company
Developed by The Electricity Council
Research Centre (ECRC), Capenhurst
and The Welsh Water Authority

Function: Aeration to enhance biodegradation.

Description: An aeration system could have applications in biochemical processes. The Maguire VO_2 system comprises essentially a Venturi and a pump. It provides a relatively high air input from a very small volume. Due to a thermophilic process it creates, almost total destruction of E. coli and Salmonella occurs at temperatures of 55°C to 65°C.

Performance: The unit is capable of increasing air input to a sludge bed by more than 30 percent in some cases, from a very small volume. The aeration tank installed by Cadbury at Marlbrook removes 90 percent of the BOD with an efficiency of 3 kg/kw and has reduced the quantity of sludge for offsite disposal by over 60 percent.

INTERNATIONAL TECHNOLOGY FACT SHEET (continued)

Limitations: None available.

Economics: A single VO_2 aerator can dissolve up to 80 kg/hr of oxygen at a cost of less than 2 p/kg. In the aeration tank installed by Cadbury at Marlbrook, the Venturi aerators reduced operating costs by 25 percent and recovered plant costs in about 1 year.

Status: Commercially available and in use.

Recommendations: No further action recommended.

Reference: Processing (News Item). "Aeration System Has New Uses." p. 9. December 1986.

SECTION 4

INDIVIDUALS CONTACTED

A large number of individuals were contacted by telephone or in person. For example, the August visit to RREL in Cincinnati resulted in contacts with a number of individuals at EPA, plus individuals at several other organizations. Contacts which provided useful information are listed below.

RREL - Cincinnati, OH

Barth, Ed - Also went to an international conference in Atlanta with plenty of s/s technology experts.

Bell, Robert - In England, did work on vegetative uptake as a treatment technology for soil contaminated with dioxins.

Dial, Clyde - Familiar with European soil cleaning technologies- traveled extensively throughout Europe researching hazardous waste management.

Hill, Ronald - Traveled to Denmark in August 1981 to meet with the Danish National Agency of Environment to discuss"Superfund" treatment techniques (SITE program).

James, Steve - SITE program contact.

Lewis, Ronald - Knows microbial degradation, particularly activities in The Netherlands.

Oberacker, Donald - Incineration. Attended a seminar in Copenhagen on municipal waste incineration, but also visitedwaste treatment facilities.

Sanning, Donald E. - Traveled to Europe in 1986; participated in NATO/CCMS study, 1984; U.S. representative on NATO/CCMS Study, 1987. Very knowledgeable about foreign technologies and hazardous waste management practices.

Schomaker, Norbert - Familiar with the NBM thermal desorption process.

Wiles, Carlton - Working with Alberta Province and Environment Canada on solidification procedures.

RREL - Edison, NJ

Freestone, Frank - Chief of Technology Evaluation Staff. Has been traveling to Europe since 1980, and knows soil washing and incineration equipment (mobile units used at Denny Farm).

Gruenfeld, Michael - Chief of Chemistry Staff. Attended NATO meetings.

Wilder, Ira - Branch Chief. Experience with Japanese technology.

Yezzi, James J. - Deputy Project Officer,Environmental Emergency Response Unit. Experience with incineration and soil washing in Europe.

USEPA - Washington, D.C.

DeRossier, Paul - OSWER, Dioxin Disposal Advisory Group. Performed work for J. Skinner to define innovative technologies. Has a good handle on European technologies.

Pheiffer, Thomas - OSWER Operations Group.

Skinner, John - Participates in many international activities, and is an editor of the book "International Perspectives on Hazardous Waste Management" (copyright 1987).

White, Donald - OSWER, knowledgeable in waste treatment and site remediation, good program perspective.

Other USEPA Offices

Coursen, Robin - Region VIII. Spent 6 months in Germany.

Dahl, Thomas - National Enforcement Investigations Center, Denver, CO. Visited UK, Denmark, Federal Republic of Germany and Holland.

Wassersug, Steve - H.W. Management Division Director in Philadelphia. Spent 3 months in Europe doing a survey of treatment technologies for Superfund sites on a German Marshall Fund Scholorship.

Wilson, John - Robert S. Kerr Environmental Laboratory, Ada, Oklahoma. Involved in work on enhanced microbial degradation and went to the Netherlands.

U.S. Office of International Activities, Washington, D.C. - Perform many Cooperative Agreements. Contact for the EPA branch is Conrad Kleveno, Associate Administrator.

Non-USEPA Organizations

Arnott, Robert - ERM, Denver, CO. Spent 16 months traveling in Europe under the German Marshall Fund looking at technologies. Worked part-time for WHO with Jim Smith.

Brown, Margaret. Byrne Brown Associates, International Consultants. Familiar with German technologies.

Christian, Mary Jo - Hazardous Waste Treatment Council.

Cywin, Al - NUS Corporation, Arlington, VA. Cleared papers for the International Conference on Frontiers in Hazardous Waste Management.

The German Marshall Fund.

Haney, Paul - Lawyer with TECHLAW, Denver, CO. Spent 6 months in Berlin with NEIC.

International Waste Technologies, Wichita, KA.

Johnston, Glen - Roy F. Weston, Westchester, PA. Supervised the report for the EPA on International Wastewater Treatment Technologies.

Smith, Jim - World Health Organization (part-time).

Stanley, David, and Kenneth Geiger - Tufts University. Prepared a report for EPA on Foreign Practices in Hazardous Waste Minimization.

World Bank - Office of Environmental and Scientific Affairs. Contact for remedial efforts is Dr. Robert Batstone.

SECTION 5

LITERATURE REFERENCES

Literature sources reviewed were drawn from three basic sources:

- Approximately 150 documents collected during a week-long visit to RREL in Cincinnati;
- Computerized and manual literature searches; and
- Documents provided by telephone contacts.

Each literature source was reviewed to select technologies for inclusion in the Fact Sheets. Many technologies were eliminated from further consideration because they were not state-of-the-art and/or were duplicative of U.S. applications. Also, many references did not actually describe specific technologies, or were duplicative of other references.

A listing of references for technologies selected for the Fact Sheets and other useful background material appears below.

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